GPG FINDINGS

# 001

MARCH 2012

# WIRELESS SENSOR NETWORKS FOR DATA CENTERS

## OPPORTUNITY

*How much energy is used by data centers in the U.S.?*

**2%**

**OF ALL U.S. ENERGY**

IS CONSUMED BY DATA CENTERS[1]

**~50%**

**GOES TO NON-IT LOADS**[2]

## TECHNOLOGY

*How do Wireless Sensor Networks save energy?*

**CAPTURE & DISPLAY CRITICAL INFORMATION IN REAL-TIME**

OPERATORS IDENTIFY WAYS TO INCREASE ENERGY- EFFICIENCY

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed the effectiveness of a wireless sensor network provided by Synapsense at the USDA National Information Technology Center in St. Louis, Missouri

## RESULTS

*How did Wireless Sensor Networks perform in M&V?*

**17%**

**ENERGY SAVINGS**

48% REDUCTION IN COOLING LOAD[3]

**EFFECTIVE TOOL**

FOR ON-GOING OPTIMIZATION OF DATA CENTERS[4]

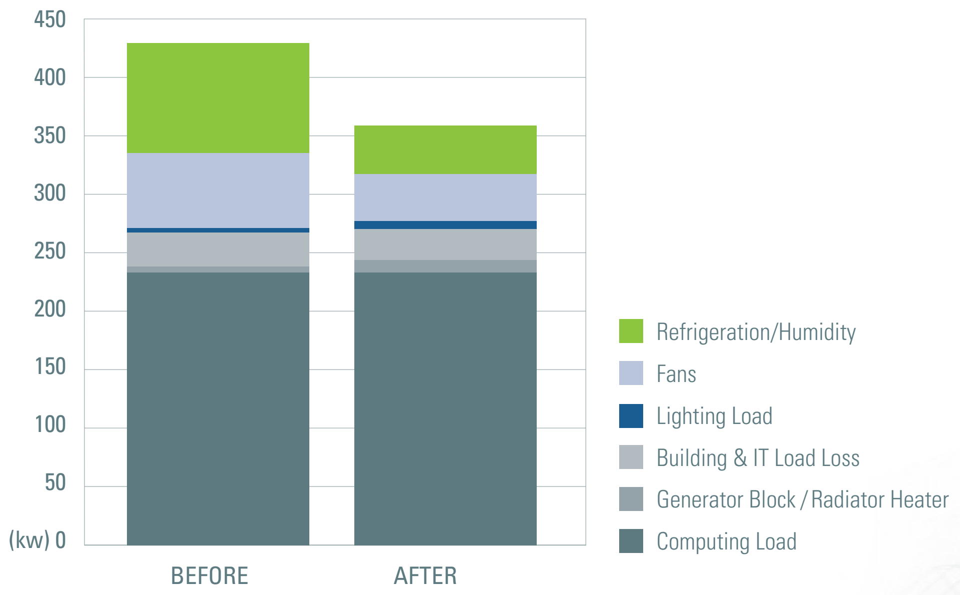
**3.4 YEARS**

PAYBACK AT $0.045 kWh

< 50% of national average $0.11 kWh[5]

### Data Center Power Usage Distribution

48% Cooling Load Reduction, 17% Overall Data Center Energy Reduction




## DEPLOYMENT

*Where does M&V recommend deploying Wireless Sensor Networks?*

**ALL DATA CENTERS***

Estimated $61 million in annual savings and annual decrease of 532,000 metric tons of CO2, if implemented by tenant agencies throughout the GSA portfolio

Data center assessment kit developed during study reduces deployment time and power interruptions during installation

[1]McKinsey & Company, "Revolutionizing Data Center Efficiency", 2008 [2]Wireless Sensor Network for Improving the Energy Efficiency of Data Centers. Rod Mahdavi, William Tschudi (LBNL), March 2012, p.27 [3]Ibid, p.29 [4]Ibid, p.7 [5]Ibid, p.29 *Subject to evaluation and approval by GSA-IT and Security

GSA

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GPG FINDINGS 002

SEPTEMBER 2012

# OCCUPANT RESPONSIVE LIGHTING

## OPPORTUNITY

*How much electricity is used for lighting in U.S. commercial buildings?*

**39%**
**OF ELECTRICITY**
GOES TO LIGHTING[1]

**1%**
**OF BUILDINGS**
HAVE ADVANCED LIGHTING CONTROLS[2]

## TECHNOLOGY

*How does Occupant Responsive Lighting save energy?*

**USES 3 CONTROL STRATEGIES**
OCCUPANCY SENSING, TIMER SCHEDULING, AND DIMMING

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed the use of responsive lighting systems in 5 federal buildings in California

## RESULTS

*How did Occupant Responsive Lighting perform in M&V?*

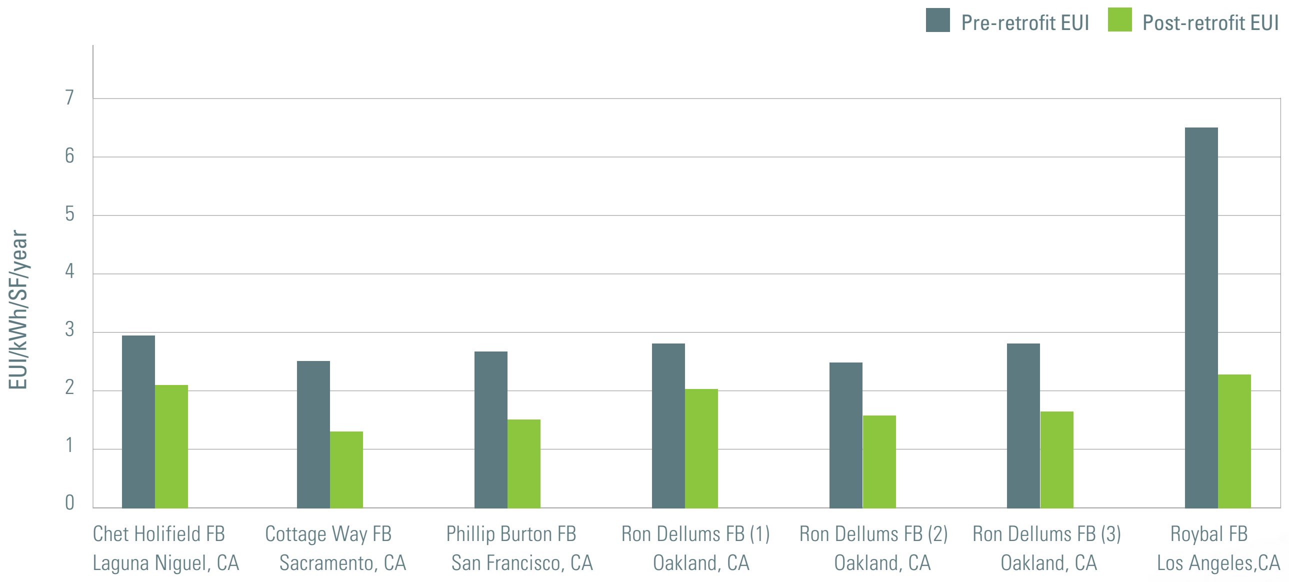
**27%-63%**
**ENERGY SAVINGS**[3]
SAVINGS VARY DEPENDING ON OPERATING HOURS & OCCUPANCY[4]

**IMPROVED**
**SATISFACTION**
BETTER QUALITY LIGHT WITH LESS GLARE WITHIN P100 STANDARDS[5]

**6**
**YEARS**
PAYBACK FOR CALL CENTERS
Lit 18 hours a day 7 days a week[6]

### Annual Energy Savings By Site

Energy savings ranged from 27% to 63%




## DEPLOYMENT

*Where does M&V recommend deploying Occupant Responsive Lighting?*

**LONG OPERATING HOURS**
Buildings with operating hours > 14 hours
Utility costs > $.11 kwh
And variable occupancy patterns

[1]Responsive Lighting Solutions. Joy Wei, Abby Enscoe, Francis Rubenstein (LBNL), September 2012, p.17 [2]Ibid, p.17 [3]Ibid, p.34 [4]Ibid, p.12 [5]Ibid, p.13 [6]Ibid, p.12

GPG FINDINGS 003

SEPTEMBER 2012

# ADVANCED POWER STRIPS FOR PLUG LOAD CONTROL

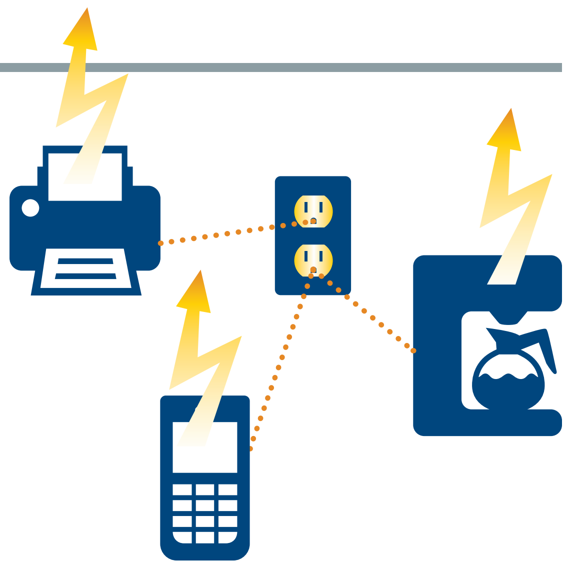
## OPPORTUNITY

*How much energy is lost to plug loads in U.S. commercial buildings?*

**25%**

**OF ELECTRICITY IS LOST TO PHANTOM POWER**

IN EFFICIENT BUILDINGS THIS CAN INCREASE TO 50%[1]



## TECHNOLOGY

*How do Advanced Power Strips save energy?*

**DE-ENERGIZE CIRCUITS**

BASED ON A TIMER, LOAD-SENSING, OR BOTH

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** tested the effectiveness of 3 plug load reduction strategies in buildings throughout GSA's Mid-Atlantic Region

## RESULTS

*How did Advanced Power Strips perform in M&V?*

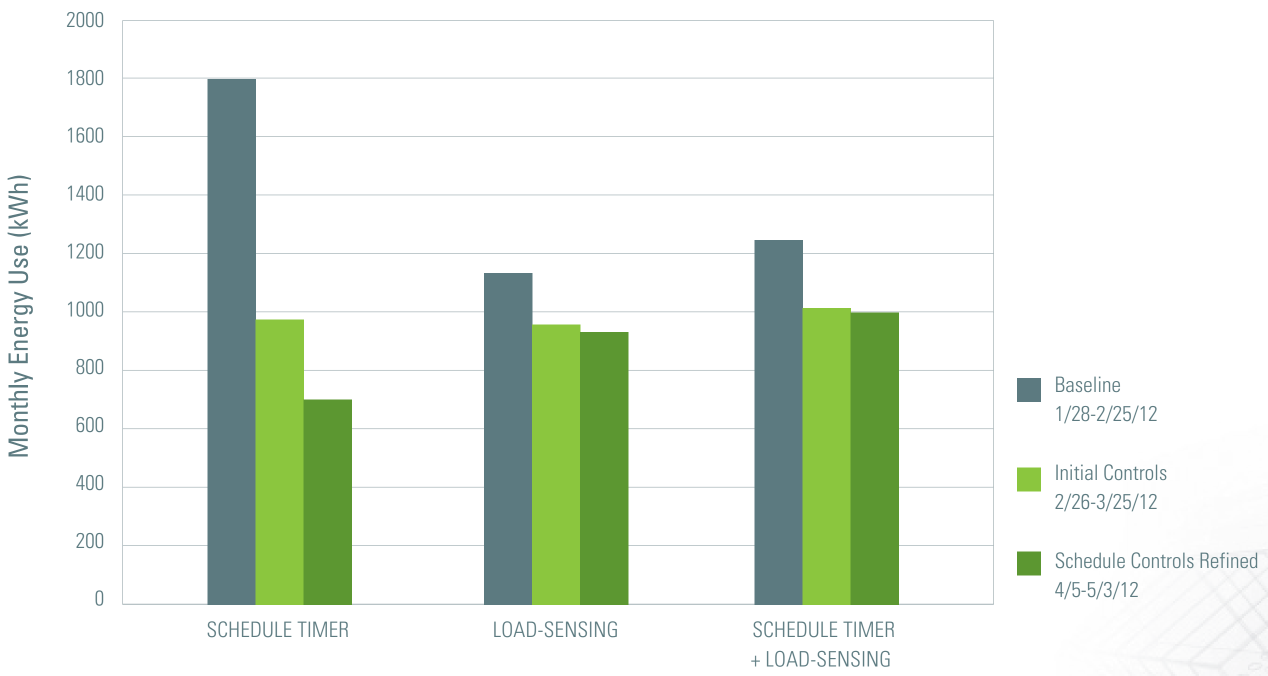
**SIMPLE**
**TIMER CONTROLS**
MOST COST-EFFECTIVE[2]

**26%**
**ENERGY SAVINGS**
AT WORKSTATIONS
with advanced computer management in place
48% IN KITCHENS & PRINTER ROOMS[3]

**< 8**
**YEARS**
PAYBACK IN ALL APPLICATIONS
< 1 year in kitchens & printer rooms[4]

### Energy Reduction for Tested Control Strategies

Schedule timer controls resulted in average-energy reduction of 48%




## DEPLOYMENT

*Where does M&V recommend deploying Advanced Power Strips?*

**DEPLOY BROADLY**

Energy savings & low payback support deployment throughout GSA's portfolio.*

[1]Plug Load Control and Behavioral Change Research in GSA Office Buildings. Ian Metzger, Dylan Cutler, Michael Sheppy (NREL), September 2012, p.1 [2]Ibid, p.4 [3]Ibid, p.4 [4]Ibid, p.4 *Subject to evaluation and approval by GSA-IT and Security

GSA

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GPG FINDINGS

# 004

UPDATED JULY 2014

# CONDENSING BOILERS

## OPPORTUNITY

*How much energy is used for heating in U.S. commercial buildings?*

**35% OF ENERGY**

GOES TO HEATING[1]

**32% OF COMMERCIAL BUILDINGS**

RELY ON BOILERS TO SUPPLY THIS HEAT[2]

## TECHNOLOGY

*How do Condensing Boilers save energy?*

**CAPTURE HEAT**

**THAT IS LOST THROUGH STEAM**

IN CONVENTIONAL BOILERS

**95% EFFICIENCY**

15% more efficient than conventional boilers

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** and **NATIONAL RENEWABLE ENERGY LABORATORY** measured the performance of condensing boilers provided by Harsco Patterson-Kelley and Cleaver-Brooks at both the Peachtree Summit Federal Building in Atlanta, Georgia and the Denver Federal Center

## RESULTS

*How did Condensing Boilers perform in M&V?*

**>14% SAVINGS**

IN NATURAL GAS CONSUMPTION[3,4]

**<130°F RETURN WATER TEMPERATURE**

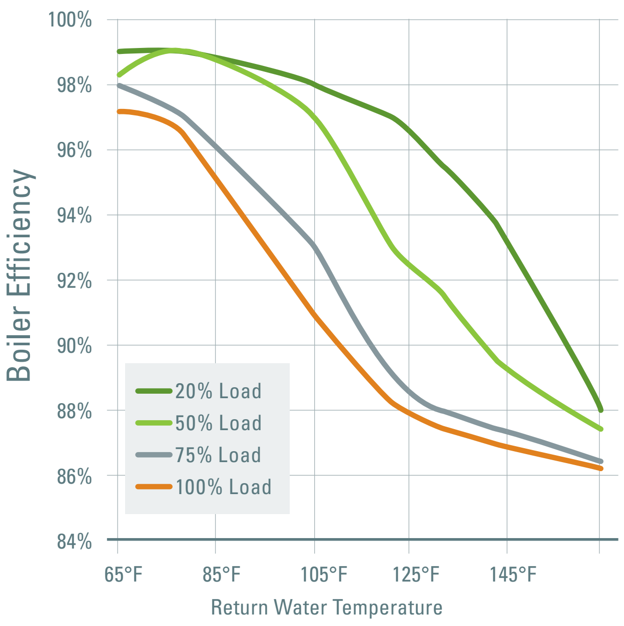
KEY TO EFFICIENCY[5]

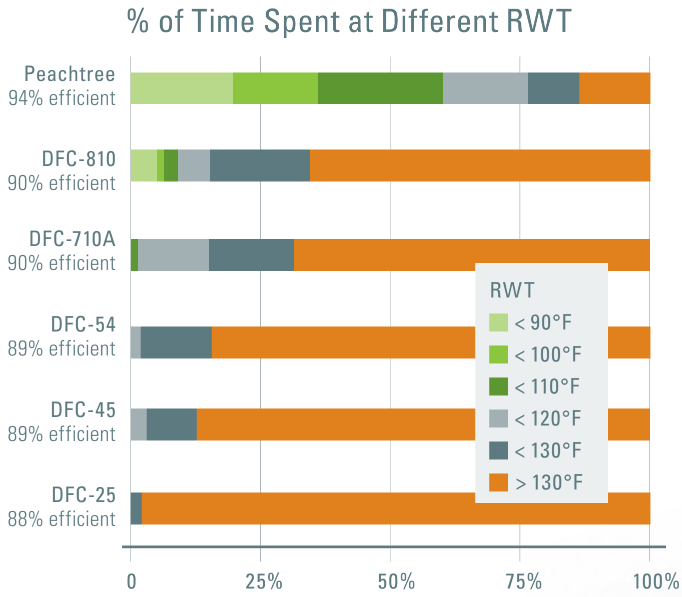
**4-7 YEARS**

PAYBACK AT ESTIMATED TYPICAL COST[6,7]

### Return Water Temperature Is Key to Efficiency

Lower RWT results in greater efficiencies




## DEPLOYMENT

*Where does M&V recommend deploying Condensing Boilers?*

**END-OF-LIFE REPLACEMENT**

OF CONVENTIONAL BOILERS WITH CONDENSING BOILERS

Life-cycle cost-effective even when only 3%-5% more efficient than high-efficiency boilers

[1]Condensing Boiler Assessment: Peachtree Summit Federal Building; Atlanta, Georgia. S.A. Parker, J. Blanchard (PNNL), November 2012, p.5 [2]Ibid, p.5 [3]Ibid, p.21 [4]Condensing Boilers Evaluation: Retrofit and New Construction Applications. Dylan Cutler, Jesse Dean, Jason Acosta, Dennis Jones (NREL), July 2014, p.26 [5]Ibid, p.4 [6]Ibid, p.27 [7]Condensing Boiler Assessment: Peachtree Summit Federal Building; Atlanta, Georgia. S.A. Parker, J. Blanchard (PNNL), November 2012, p.24

GPG FINDINGS 005

DECEMBER 2012

# PHOTOVOLTAIC SYSTEM PERFORMANCE

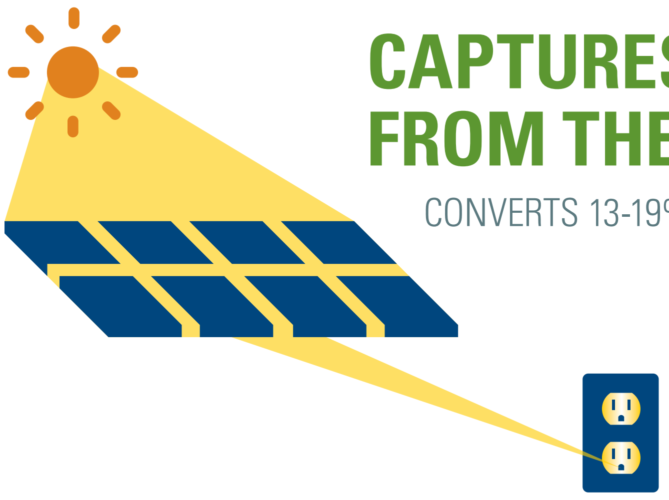
## OPPORTUNITY

*How much energy is generated by photovoltaics in GSA buildings?*

**1%** **OF GSA'S ENERGY** COMES FROM SOLAR[1]

## TECHNOLOGY

*How does PV work?*



**CAPTURES ENERGY FROM THE SUN**

CONVERTS 13-19% INTO ELECTRICITY[2]

## M&V

*Where did Measurement and Verification occur?*

**SANDIA NATIONAL LABORATORIES** and **NEW MEXICO STATE UNIVERSITY'S COLLEGE OF ENGINEERING** assessed performance of 5 PV installations provided by Sunpower, Evergreen Solar, Solyndra, United Solar Ovonic, and Abound Solar at the Major General Emmett J. Bean Federal Center in Indianapolis, Indiana

## RESULTS

*How did photovoltaics perform in M&V?*

**8%** **OF SITE LOAD ENERGY** GENERATED FROM PV[3]

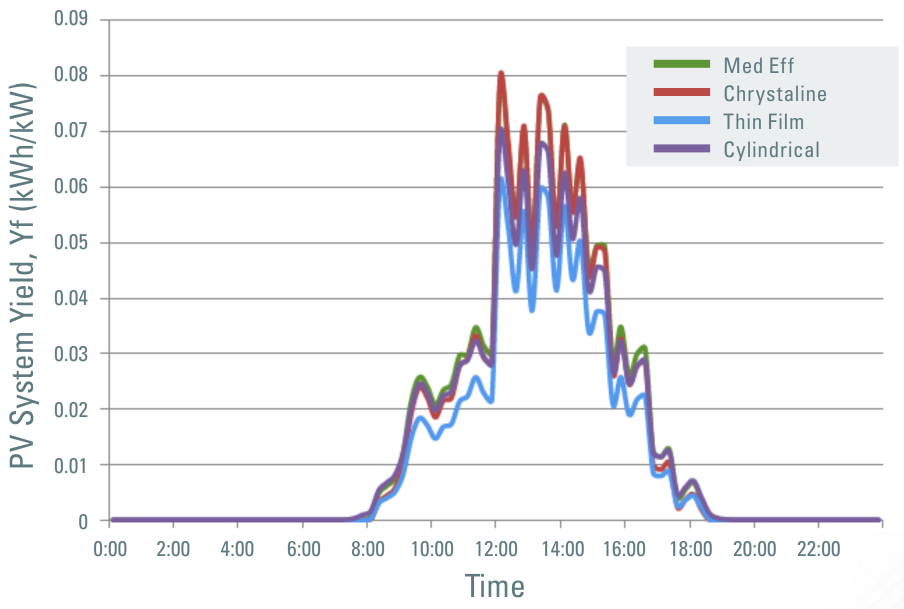
**PARITY** **AMONG SYSTEMS** UNDER CLOUDY SKIES[4]

**19** **YEAR** PAYBACK[5]

Steady decline in PV cost will further improve payback[6]

### Laboratory Systems Perform Similarly Under Cloudy Skies

PV System Yield on Cloudy Day, March 3, 2012




## DEPLOYMENT

*Where does M&V recommend deploying photovoltaics?*

**PV EFFECTIVE EVEN IN DIFFUSE, 4-SEASON CLIMATES**

**PRICE SHOULD DRIVE PV SELECTION**

Modeling tools produce accurate simulations for both sunny and cloudy climates

[1]GSA Energy Usage Analysis System, 2013 [2]Photovoltaic System Performance. Andrew L. Rosenthal (USDOE, NMSU, SNL) December 2012, p.5 [3]Ibid, p.12 [4]Ibid, p.1 [5]Ibid, p.12 [6]Ibid, p.3

GPG FINDINGS

# 006

DECEMBER 2012

# VARIABLE REFRIGERANT FLOW

## OPPORTUNITY

*How much energy is used for heating, ventilation and air conditioning (HVAC) in U.S. office buildings?*

**34%**
**OF ENERGY**
GOES TO HVAC[1]

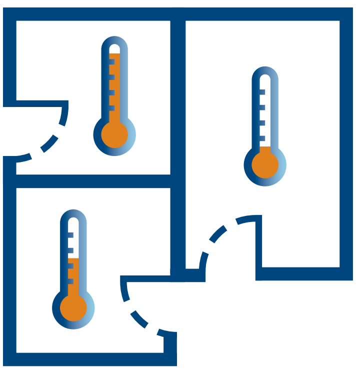
**3%**
**OF U.S. OFFICE BUILDINGS RELY ON VRF[2]**
PRIMARY HVAC SYSTEM IN EUROPE, JAPAN AND CHINA[3]

## TECHNOLOGY

*How does VRF work?*

**PROVIDES INDEPENDENT TEMPERATURE CONTROL**
TO ROOMS THROUGHOUT BUILDING

**USES REFRIGERANT**
AS COOLING/HEATING MEDIUM; SUBSTITUTING THIN PIPES FOR DUCTWORK



## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** drew from a wide variety of sources to evaluate the performance of VRF for GSA buildings

## RESULTS

*How did VRF perform in M&V?*

**34%**
**ENERGY SAVINGS**
PROJECTED RELATIVE TO CODE-COMPLIANT HVAC[4]

**THIN**
**PROFILE**
ADVANTAGEOUS IN HISTORIC BUILDINGS WITH LIMITED ROOM FOR DUCTWORK[5]

**COST-**
**EFFECTIVE**
WHEN THE PREMIUM IS < $4/SQ.FT. COMPARED TO CODE-COMPLIANT HVAC[6]

## Projected Payback for VRF vs VAV

Reasonable paybacks achievable (shown in white)

### VRF vs VAV with Gas Reheat or Cav

34% Projected Energy Cost Savings

| Added Cost $/ft² | Energy Cost Savings, $/ft²: $.10 | $.14 | *$.18 | $.22 | $.26 | $.30 | $.34 | $.38 |
|---|---|---|---|---|---|---|---|---|
| $1 | 10 | 7 | 6 | 5 | 4 | 3 | 3 | 3 |
| $2 | 20 | 14 | 11 | 9 | 8 | 7 | 6 | 5 |
| $3 | 30 | 21 | 17 | 14 | 12 | 10 | 9 | 8 |
| **$4 | 40 | 29 | 22 | 18 | 15 | 13 | 12 | 11 |
| $5 | 50 | 36 | 28 | 23 | 19 | 17 | 15 | 13 |
| $6 | 60 | 43 | 33 | 27 | 23 | 20 | 18 | 16 |

### VRF vs VAV with Electric Reheat

45% Projected Energy Cost Savings

| Added Cost $/ft² | Energy Cost Savings, $/ft²: $.13 | $.19 | *$.24 | $.29 | $.34 | $.40 | $.45 | $.50 |
|---|---|---|---|---|---|---|---|---|
| $1 | 8 | 5 | 4 | 3 | 3 | 3 | 2 | 2 |
| $2 | 15 | 11 | 8 | 7 | 6 | 5 | 4 | 4 |
| $3 | 23 | 16 | 13 | 10 | 9 | 8 | 7 | 6 |
| **$4 | 30 | 22 | 17 | 14 | 12 | 10 | 9 | 8 |
| $5 | 38 | 27 | 21 | 17 | 15 | 13 | 11 | 10 |
| $6 | 45 | 32 | 25 | 21 | 17 | 15 | 13 | 12 |

* Average GSA Portfolio Energy Cost Savings (based on GSA average usage of 60.7 kBtu/ft², GSA average cost of $0.89/therm, and EIA average cost of $0.10/kWh)

** Average Added Cost

## DEPLOYMENT

*Where does M&V recommend deploying VRF?*

**PILOT PROJECTS**
Research on field performance is limited

[1]Variable Refrigerant Flow Systems. Brian Thornton, Anne Wagner (PNNL), December 2012, p.4 [2]Ibid, p.11 [3]Ibid, p.4 [4]Ibid, p.13 [5]Ibid, p.24 [6]Ibid, p.46

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GPG FINDINGS 007

DECEMBER 2013

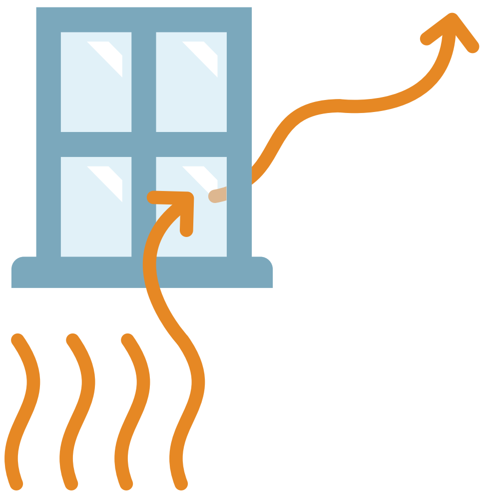
# HI-R LOW-E WINDOW RETROFIT SYSTEM

## OPPORTUNITY

*How much energy is lost through inefficient windows in commercial buildings?*

**23% ENERGY**

USED TO HEAT & COOL BUILDINGS IS LOST THROUGH INEFFICIENT WINDOWS[1]



## TECHNOLOGY

*How do Window Panel Retrofits save energy?*

**IMPROVE THERMAL PERFORMANCE**

WITH LOW-E WINDOW PANELS

**PRE-MANUFACTURED**

LIKE STORM WINDOWS; SIMPLIFYING INSTALLATION

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed the impact of Hi-R Low-e window panel retrofits provided by Serious Energy in a Provo, Utah federal office building.

## RESULTS

*How did Window Panel Retrofits perform in M&V?*

**41%**

**HEATING SAVINGS IN WINTER[2]**

ESTIMATED SAVINGS FOR ENTIRE BUILDING HEATING AND COOLING: 11%[3]

**QUICK**

**INSTALLATION[4]**

IMPROVED VISUAL AND THERMAL COMFORT[5]

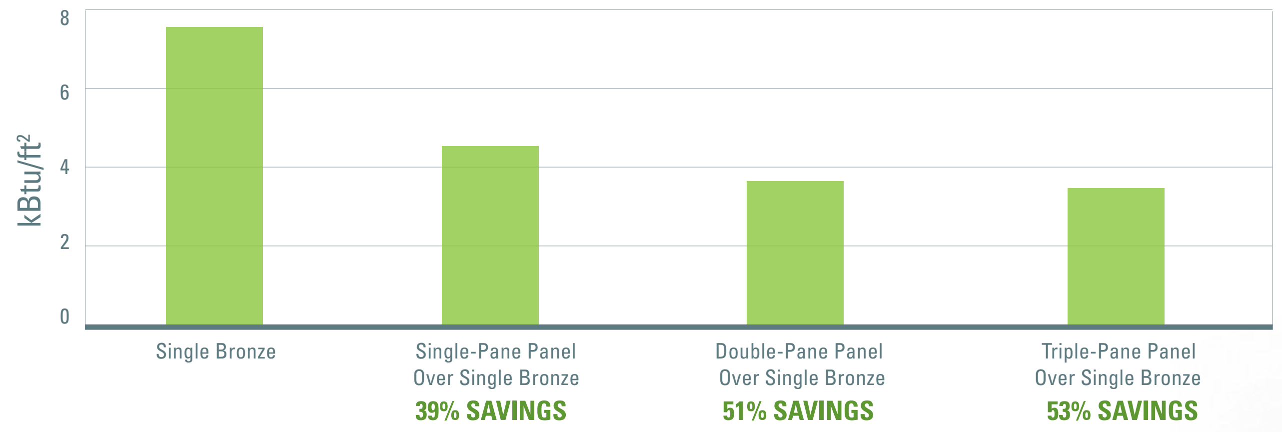
**<9**

**YEARS**

PAYBACK FOR TRIPLE-PANE; DOUBLE-PANE WILL BE SHORTER[6]

### Savings Diminish with Triple-Pane Hi-R Window Panel Retrofit

COMFEN results compared to base configuration of single pane with bronze film




## DEPLOYMENT

*Where does M&V recommend deploying Window Panel Retrofits?*

**BUILDINGS IN COLD CLIMATES**

WITH SINGLE-PANE WINDOWS

Double-pane retrofits recommended, as triple-pane offers diminishing returns
Site-specific evaluation is critical

[1]Highly Insulating Window Panel Attachment Retrofit. Charlie Curcija, Howdy Goudey, Robin Mitchell, Erin Dickerhoff (LBNL), December 2013, p.3 [2]Ibid, p.26 [3]Ibid, p.39 [4]Ibid, p.7 [5]Ibid, p.26,35 [6]Ibid, p.2

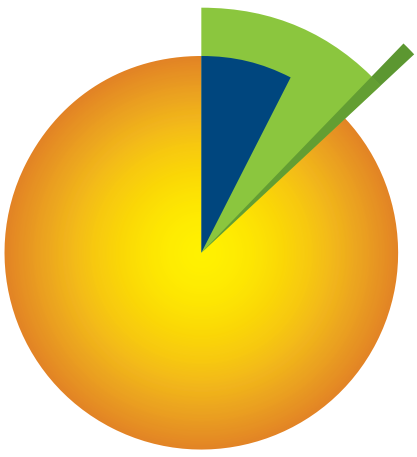
GPG FINDINGS 008

DECEMBER 2013

# ON-SITE PHOTOVOLTAIC GUIDANCE

## OPPORTUNITY

*How is GSA meeting federal mandates for renewable energy?*



**7.5%** Federal mandate goal for renewable energy[1]

**13.2%** GSA renewable energy purchased[2]

**1%** Solar energy production from GSA buildings[3]

Additional .05% from wind & geothermal

## TECHNOLOGY

*How was the study conducted?*

**POLICY REVIEW; SURVEYS AND INTERVIEWS WITH PROJECT TEAMS**

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** collected best practices and lessons learned from 63 of the 74 GSA PV installations nationwide

## RESULTS

*What did we learn in M&V?*

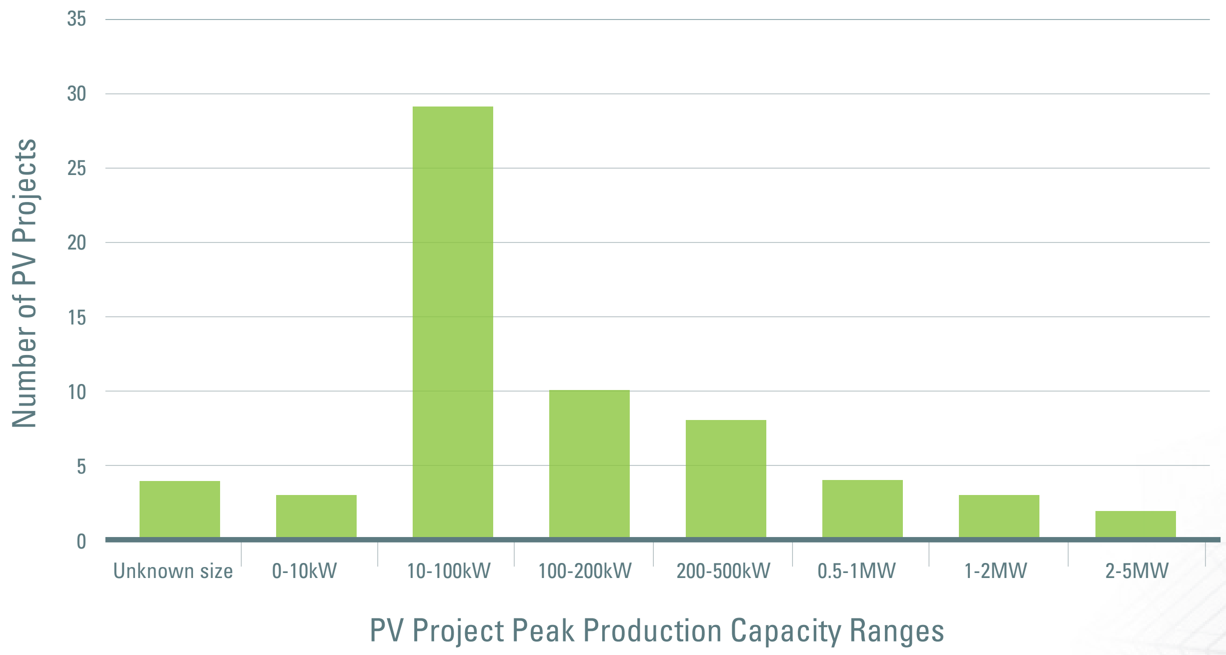
**DIVERSE PORTFOLIO**
SYSTEM CAPACITY RANGED FROM 10KW TO 5MW[4]

**CHALLENGES NUMEROUS & UNIVERSAL[5]**
PROJECT MANAGEMENT, SITE, INTERCONNECTION, TECHNICAL, AND ECONOMIC

**RISKS MITIGATED**
BY ADVANCE PLANNING AND PROJECT MANAGEMENT[6]

### Projects in NREL Study, by System Capacity

Of the 63 projects included, capacity ranges widely




## FOR MORE INFORMATION

*Where to find addtional information?*

**ON-SITE PV GUIDANCE REPORT**

Lessons Learned & Best Practices available at gsa.gov/gpg

[1] EPA, http://www.epa.gov/oaintrnt/greenpower/requirements.htm [2] GSA Energy Usage Analysis System, 2013 [3] ibid
[4] On-Site Photovoltaic Guidance. Tom Harris, Ian Metzger, Alicen Kandt, Graham Hill, Marianne Kaiser (NREL), October 2013, p.5
[5] Ibid, p.21 [6] Ibid, p.28

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DECEMBER 2013

# VARIABLE-SPEED MAGNETIC BEARING CHILLER

## OPPORTUNITY

*How much energy is used for space cooling in U.S. office buildings?*

**10%**
**OF ENERGY**
GOES TO SPACE COOLING[1]

**32%**
**OF COMMERCIAL BUILDINGS**
RELY ON CHILLERS TO PROVIDE THIS COOLING[2]

## TECHNOLOGY

*How do maglev chillers save energy?*

**ELIMINATE FRICTION**
WITH MAGNETIC BEARINGS

**IMPROVE EFFICIENCY AT PARTIAL LOADS**
WITH VARIABLE SPEED DRIVE

**35%**
**MORE EFFICIENT**
THAN FEMP-DESIGNATED HIGH-EFFICIENCY ROTARY SCREW CHILLERS

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed the performance of a variable-speed oil-free centrifugal chiller with magnetic bearings manufactured by Danfoss at the George Howard, Jr. Federal Building in Pine Bluff, Arkansas

## RESULTS

*How did maglev chillers perform in M&V?*

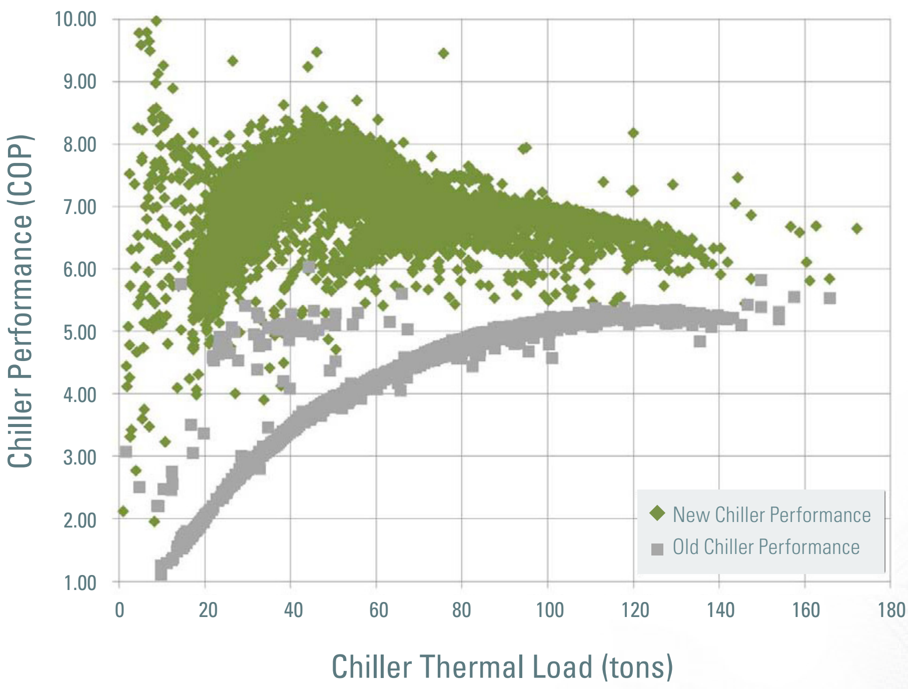
**42%**
**ENERGY SAVINGS**
AS COOLING LOADS DECREASE, EFFICIENCY INCREASES[3]

**QUIET**
**PERFORMANCE**
ALLOWS CHILLERS TO BE PLACED CLOSER TO OCCUPANT SPACES[4]

**<5**
**YEARS**
PAYBACK
after normalizing for payment structure & utility costs[5]

### Efficiency of Maglev Chiller Increases as Load Is Reduced

Maglev chiller efficiency is highest between 40 to 50 tons (27 to 33% of nominal full load)
Incumbant chiller efficiency continuously decreases as chiller load is reduced




## DEPLOYMENT

*Where does M&V recommend deploying maglev chillers?*

**END-OF-LIFE REPLACEMENT**
OF POSITIVE DISPLACEMENT CHILLERS WITH MAGLEV CHILLERS

[1]Variable-speed Oil-free Centrifugal Chiller with Magnetic Bearings Assessment; George Howard, Jr. Federal Building and U.S.Courthouse, Pine Bluff, Arkansas. S.A.Parker, J.Blanchard (PNNL), December 2013, p.1 [2]Ibid, p.1 [3]Ibid, p.3 [4]Ibid, p.34 [5]Ibid, p.26

MARCH 2014

# ELECTROCHROMIC AND THERMOCHROMIC WINDOWS

## OPPORTUNITY

*How much energy can be saved by daylighting U.S. office buildings?*

**1 billion**

**MBTU OF LIGHTING ENERGY**

CAN BE SAVED BY TAKING ADVANTAGE OF DAYLIGHT[1]

## TECHNOLOGY

*How do chromogenic windows save energy?*

**REDUCE SOLAR HEAT GAIN**

BY TRANSITIONING DYNAMICALLY FROM CLEAR TO DARK

**ELECTROCHROMIC (EC)**

Use switches or automated building control systems to actively tint windows via electric current

**THERMOCHROMIC (TC)**

Use adhesive coating to adjust tinting passively with window surface temperature

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** measured performance and occupant satisfaction of electrochromic and thermochromic windows provided by SageGlass and RavenBrick at the Denver Federal Center in Colorado

## RESULTS

*How did chromogenic windows perform in M&V compared to baseline low-e windows?*

**9-10%**

**HVAC COOLING SAVINGS[2]**

48-58% REDUCTION IN HEAT GAIN[3]

**PRESERVED VIEWS**

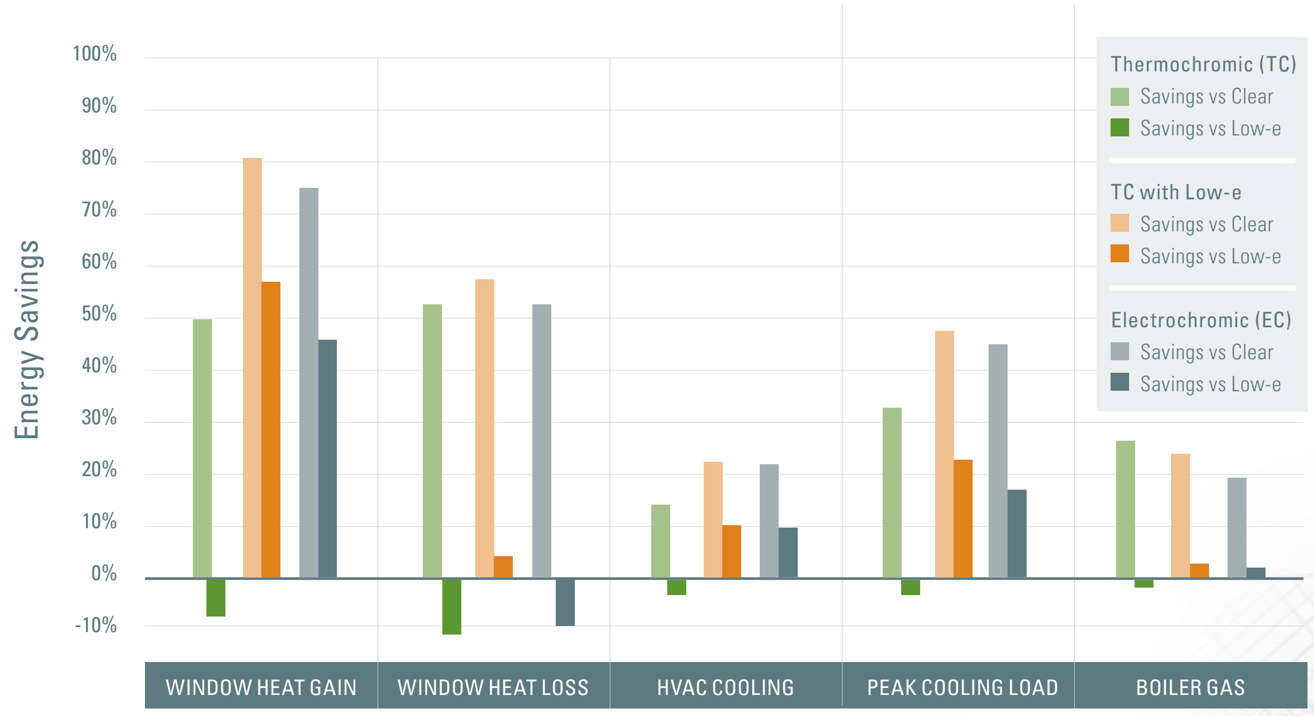
EC TINTED TO DARK BLUE[4]; TC PERFORMANCE SENSITIVE TO SURROUNDING SURFACE GEOMETRY[5]

**CAPTURED BENEFIT**

OF NATURAL DAYLIGHTING

Provided less glare[6]

## Modeled Energy Savings Comparing TC and EC vs Clear and Low-e




## DEPLOYMENT

*Where does M&V recommend deploying chromogenic windows?*

**FURTHER EVALUATION**

GSA is undertaking further evaluations of EC WINDOWS in high-rise curtain wall applications with lighting that adjusts in response to daylight

[1]A Pilot Demonstration of Electrochomic and Thermochromic Windows in the Denver Federal Center, Building 41, Denver, Colorado. Eleanor S. Lee (LBNL), March 2014, p.12 [2]Ibid, p.51 [3]Ibid, p.54 [4]Ibid, p.17 [5]Ibid, p.50 [5]Ibid, p.10

GPG FINDINGS 011

MARCH 2014

# VACUUM INSULATED PANELS IN ROOFING APPLICATIONS

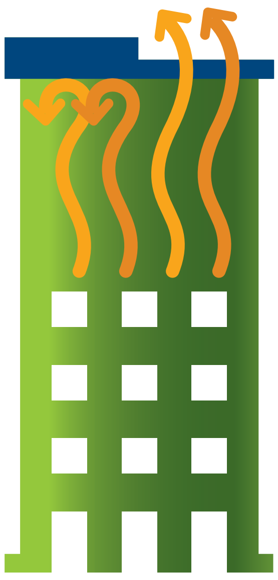
## OPPORTUNITY

*How much energy is used for heating, ventilation and air conditioning (HVAC) in U.S. office buildings?*

**37%**

**OF ENERGY**

GOES TO HVAC[1]



A LARGE PERCENTAGE ROUTINELY ESCAPES THROUGH THE BUILDING ENVELOPE

## TECHNOLOGY

*How do VIPs save energy?*

**R-50 INSULATION VALUE**

WITHIN A THIN PROFILE, 1" COMPARED TO 15" FOR CONVENTIONAL

## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** evaluated the performance of a VIP retrofit provided by Thermal Visions, Inc. at the US Post Office and Courthouse in Camden, New Jersey

## RESULTS

*How did VIPs perform in M&V?*

**8-10%**

**ENERGY SAVINGS**

WHEN COMPARED TO CODE-COMPLIANT ROOFS[2]

**ROBUST**

**PERFORMANCE**

WITH PROPER PLANNING[3]

**SAVINGS FOR R-50**

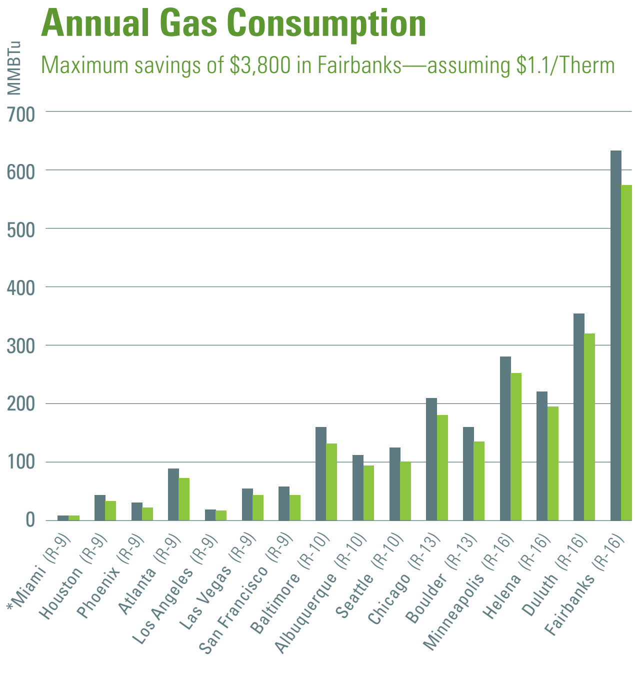
GREATEST IN SINGLE-STORY BUILDINGS IN EXTREME CLIMATES[4]

### Modeled Energy Use in a Single-Story Office Building

Largest savings in extreme climate zones, such as Fairbanks and Phoenix

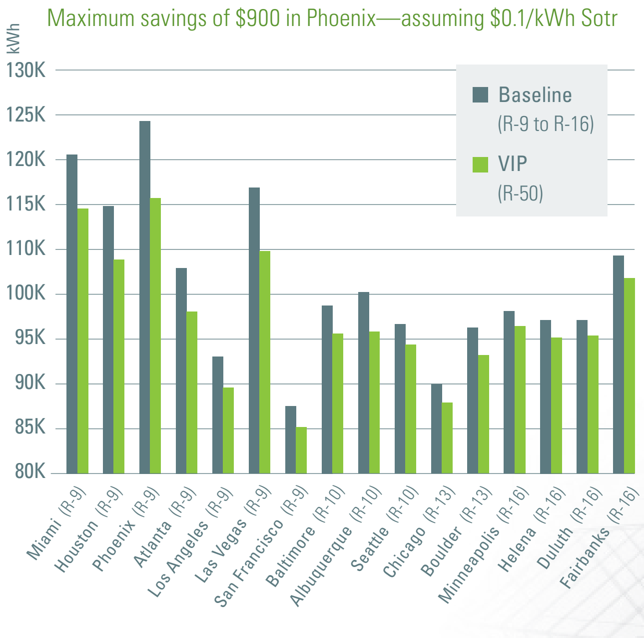
**Annual Gas Consumption**

Maximum savings of $3,800 in Fairbanks—assuming $1.1/Therm




**Annual Electricity Consumption**

Maximum savings of $900 in Phoenix—assuming $0.1/kWh Sotr




*Cities listed by climate zone from Hot-Humid (1A) to Subarctic (8A)[1]

## DEPLOYMENT

*Where does M&V recommend deploying VIPs?*

**RETROFITS**

WHERE R-50 IS REQUIRED AND INSTALLING CONVENTIONAL INSULATION NECESSITATES COSTLY ALTERATIONS

[1] Vacuum Insulated Panels in a Roofing Application Camden U.S. Post Office and Courthouse Camden, New Jersey. Dan Howett, Therese Stovall, Mahabir Bhandari, Kaushik Biswas (ORNL), March 2014, p.1 [2] Ibid, p.15 [3] Ibid, p.2 [4] Ibid, p.2

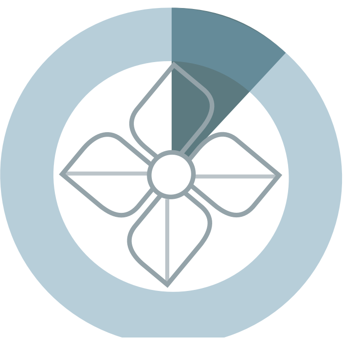
MARCH 2014

# FAN BELTS: SYNCHRONOUS AND COGGED

## OPPORTUNITY

*How much energy is used for ventilation in U.S. office buildings?*

**12%**
**OF ELECTRICITY**
GOES TO FAN VENTILATION[1]



**ADDITIONAL SAVINGS POSSIBLE**
Belt-driven fans are also used in non-ventilation applications

## TECHNOLOGY

*How do synchronous and cogged fan belts save energy?*

**REDUCE FRICTION AND BENDING RESISTANCE**
BY NOTCHING THE INNER SIDE OF THE BELT

SYNCHRONOUS BELTS ALSO **REDUCE SLIPPAGE** BY INTEGRATING TEETH WITH SLOTS ON THE MOTOR PULLEY

**2-5%**
**MORE EFFICIENT**
THAN STANDARD V-BELTS

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** measured the performance of cogged V-belts and synchronous drive belts provided by the Gates Corporation at the Byron G. Rodgers Federal Building and U.S. Courthouse in Denver, Colorado

## RESULTS

*How did synchronous and cogged fan belts perform in M&V?*

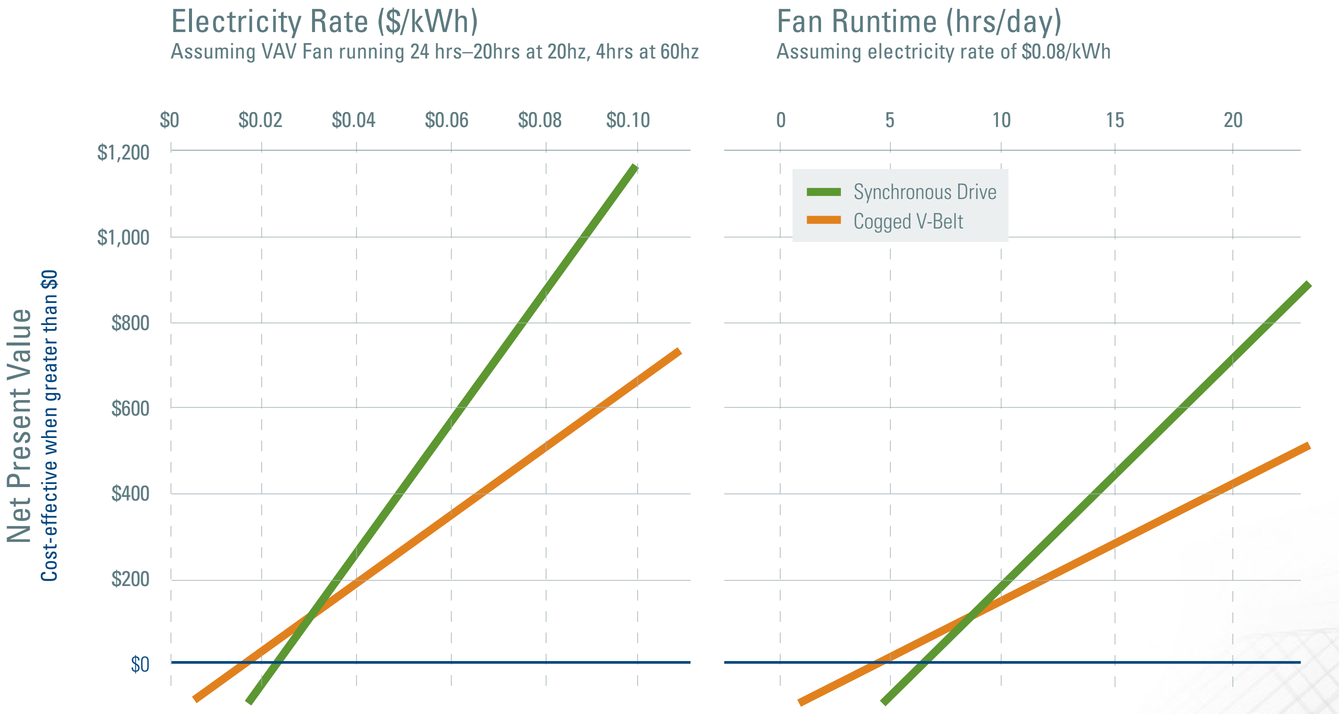
**2-20%**
**ENERGY SAVINGS**
FOR SYNCHRONOUS ON VFD
2% AT 60 HZ, 20% AT 15 HZ
Cogged fan belts offered half the savings[2]

**75%**
**LOWER O&M**
FOR SYNCHRONOUS
Cogged O&M equivalent to standard V-belts[3]

**<4**
**YEARS**
PAYBACK FOR SYNCHRONOUS[4]
Repeat installations have immediate payack; Cogged payback < 1 year [5]

### Net Present Value as a Function of Electricity Rates & Fan Runtime

Synchronous cost-effective at $0.024/kWh or 6.8 hrs/day; Cogged cost-effective at $0.015/kWh or 4.3 hrs/day




## DEPLOYMENT

*Where does M&V recommend using synchronous and cogged fan belts?*

**REPLACE V-BELTS WITH SYNCHRONOUS DRIVE BELTS ON ALL VFD FANS**

Belts on fans with high operating hours should be replaced first

**ON CV FANS, REPLACE V-BELTS AT END-OF-LIFE WITH COGGED V-BELTS**

[1] Synchronous and Cogged Fan Belt Assessment. Dylan Cutler, Jesse Dean, Jason Acosta (NREL), March 2014, p.1 [2] Ibid, p.2 [3] Ibid, p.3 [4] Ibid, p.5 [5] Ibid, p.4

MARCH 2014

# INDIRECT EVAPORATIVE COOLER

## OPPORTUNITY

*How much energy is used for air conditioning in the U.S.?*

**15%**
**OF ENERGY**
GOES TO AIR CONDITIONING[1]

**LARGEST CONTRIBUTOR**
TO PEAK DEMAND, GRID FAILURES AND BLACKOUTS[2]

## TECHNOLOGY

*How do Indirect Evaporative Coolers save energy?*

**REMOVE HEAT AND MOISTURE**
WITH UNIQUE AIR-PROCESSING TECHNOLOGY

**57-92% MORE EFFICIENT**
THAN CODE-COMPLIANT ROOF-TOP UNITS (RTU)[3]

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** assessed the performance of 3 multistaged IEC units provided by Coolerado and deployed at the Denver Federal Center in Colorado

## RESULTS

*How did Indirect Evaporative Coolers perform in M&V?*

**80%**
**ENERGY SAVINGS**[4]
INCREASED WATER USAGE (3 GALLONS/ TON-HR ) COMPARED TO TYPICAL RTU[5]

**POSITIVE**
**THERMAL COMFORT**
AS DEFINED BY ASHRAE[6]

**<15**
**YEARS**
AVERAGE PAYBACK FOR DATACENTERS[7]

### Tarket Markets Favor Dry Climate Zones (Subtype B)

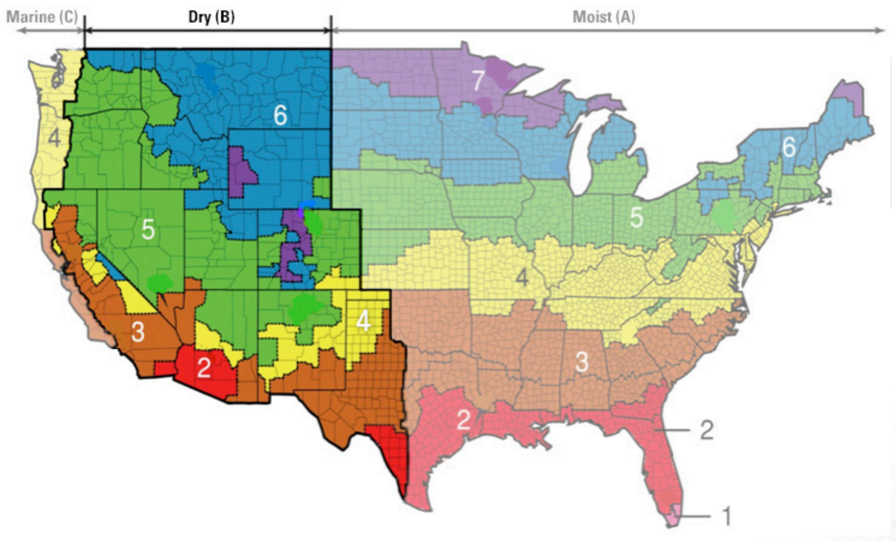
Data centers in ASHRAE climate zones 2B - 6B are top target market

**TOP 3 TARGET MARKETS**

Data Centers
2B – 6B
Retrofit & New Construction

Outside Air Pre-Conditioner
2B, 3B
Retrofit onto RTUs with EER ≤ 12

Zone Cooler
4B – 6B
Retrofit & New Construction




## DEPLOYMENT

*Where does M&V recommend deploying Indirect Evaporative Coolers?*

**DRY CLIMATES**

**Data centers :** ASHRAE climate zones 2B - 6B
**Outside air pre-conditioner :** ASHRAE climate zones 2b, 3b
**Zone cooler :** ASHRAE climate zones 4b- 6B

[1]Multistaged Indirect Evaporative Cooler Evaluation. Jesse Dean, Ian Metzger (NREL), March 2014, p.7 [2]Ibid, p.7 [3]Ibid, p.3 [4]Ibid, p.5 [5]Ibid, p.27 [6]Ibid, p.25 [7]Ibid, p.30

GPG FINDINGS

# 014

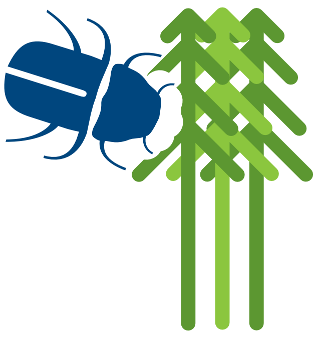
JUNE 2014

# WOOD-PELLET BIOMASS BOILERS

## OPPORTUNITY

*What are the benefits to using Biomass Boilers?*

**DRIVE USE OF LOCALLY SOURCED RENEWABLE ENERGY**



**TAKE ADVANTAGE OF WASTE WOOD**

PINE-BEETLE INFESTATION HAS KILLED 17.7 MILLION ACRES OF U.S. FOREST[1]

## TECHNOLOGY

*How do Biomass Boilers work?*

**POWER HOT-WATER-HEATING SYSTEMS**

WITH SOLID WOOD FUEL

**85%-90%**

**EFFICIENCY RATING**

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** evaluated efficiency, cost-effectiveness, and operational functionality of a 1-million BTU biomass boiler provided by Advanced Climate Technologies at the Federal Building in Ketchikan, Alaska

## RESULTS

*How did Biomass Boilers perform in the M&V?*

**85.6%**

**BOILER EFFICIENCY**

AT 45% PARTIAL LOAD[2]; INCREASED LOAD WILL INCREASE EFFICIENCY[3]

**HIGH**

**FUNCTIONALITY**

LOW O&M COSTS[4]

**<5**

**YEARS**

PAYBACK OPERATING AT 75% CAPACITY WITH AVERAGE PELLET COSTS[5]

### Payback Varies by System Size and Pellet Cost

Savings are greatest with larger systems and lower fuel costs

Pellet Cost ($/ton)

PAYBACK IN YEARS

| System Size (BTUs/hr) | $400 | $350 | $300 | $250 | $200 |
|---|---|---|---|---|---|
| 500,000 | 30.7 | 10.7 | 6.5 | 4.7 | 3.6 |
| 1,000,000 | 24.1 | 8.4 | 5.1 | 3.6 | 2.8 |
| 1,500,000 | 20.9 | 7.3 | 4.4 | 3.2 | 2.5 |
| 2,000,000 | 18.9 | 6.6 | 4.0 | 2.9 | 2.2 |
| 2,500,000 | 17.5 | 6.1 | 3.7 | 2.6 | 2.1 |
| 3,000,000 | 16.4 | 5.7 | 3.5 | 2.5 | 1.9 |
| 3,500,000 | 15.6 | 5.4 | 3.3 | 2.4 | 1.8 |
| 4,000,000 | 14.8 | 5.2 | 3.1 | 2.2 | 1.8 |

< 2
< 3
< 5
< 10
10+

**Diesel Price $3.63/gallon; 75% capacity factor**

(At a 50% capacity factor, the payback period increases 30%)

## DEPLOYMENT

*Where does M&V recommend deploying Biomass Boilers?*

**HOT-WATER HEATED FACILITIES USING FUEL OIL**

Most cost-effective for buildings in cold northern climates within 50 miles of a biomass pellet mill

[1]US Forest Service, Western Bark Beetle Strategy, Human Safety, Recovery and Resiliency, 7/11/2011 [2]Wood-Pellet-Fired Biomass Boiler Project at the Ketchikan Federal Building. Gregg Tomberlin (NREL), June 2014, p3 [3]Ibid, p.12 [4]Ibid, p.23 [5]Ibid, p.29

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg

GPG FINDINGS 015

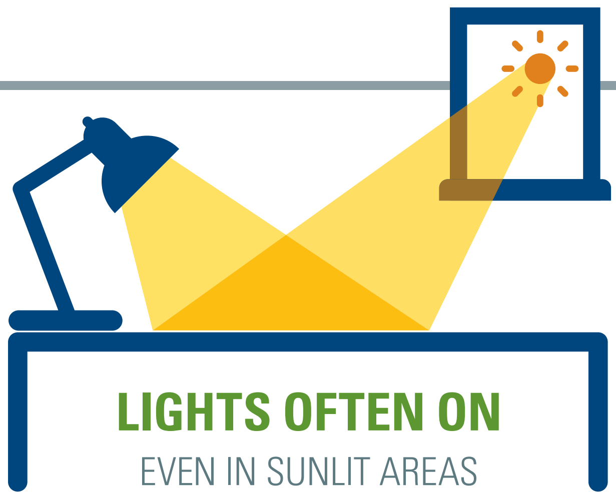
JULY 2014

# INTEGRATED DAYLIGHTING SYSTEMS

## OPPORTUNITY

*How much energy is used for lighting in U.S. commercial buildings?*

**26%**
**OF ELECTRICITY**
GOES TO LIGHTING[1]




## TECHNOLOGY

*How do Integrated Daylighting Systems save energy?*

**AVAILABLE NATURAL LIGHT**
OFFSETS USE OF ELECTRIC LIGHT

EFFECTIVE WHERE PERIMETER DEPTH IS TWO TIMES THE MAXIMUM WINDOW HEIGHT

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** measured IDS performance at 5 federal buildings to evaluate incremental savings from daylight harvesting

## RESULTS

*How did Integrated Daylighting perform in M&V?*

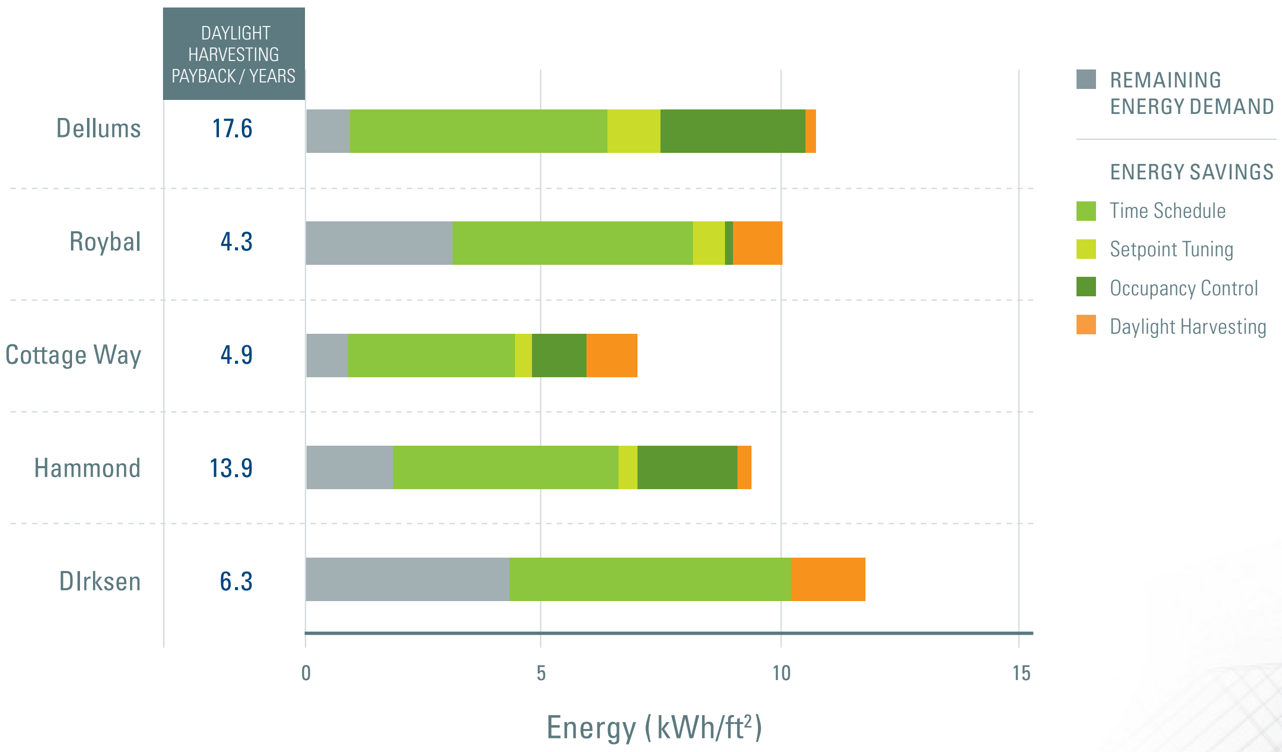
**27%**
**AVERAGE SAVINGS**
0.84 KWH/FT$^2$

**BEST PRACTICES**
UNOBSTRUCTED SKY VIEWS, LIMITED SEASONAL VARIATION, WINDOW-TO-WALL RATIO 0.5, VISIBLE TRANSMITTANCE OF 60%[3]

**<6 YEARS PAYBACK**
WITH HIGH OCCUPANCY[4]

### Lighting Energy Savings Control Strategies

Increased savings from Occupancy Control leaves little room for savings from Daylight Harvesting




## DEPLOYMENT

*Where does M&V recommend deploying Integrated Daylighting?*

**SITES WITH HIGH LIGHTING USE**

New construction and retrofits with existing lighting power density greater than 1.1 W/ft$^2$ and energy use intensity greater than 3.3 kWh/ft$^2$

Results are for fluorescent lamps, LED lamps have different performance characteristics

[1]Integrated Daylighting Systems. Alastair Robinson, Claudine Custodio, Steven Selkowitz (LBNL), July 2014, p.13 [2]Ibid, p.42
[3]Ibid, p.100 [4]Ibid, p.7,39

GPG FINDINGS **016**

JANUARY 2015

# PHOTOVOLTAIC-THERMAL HYBRID SOLAR SYSTEM

## OPPORTUNITY

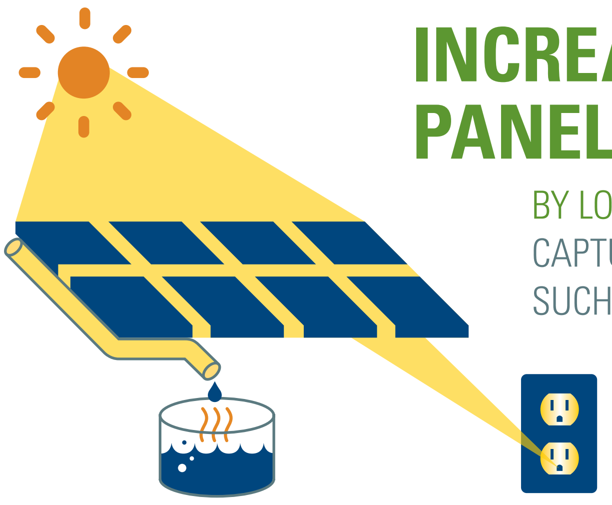
*What are the renewable energy goals of federal mandates?*

**7.5%**
**OF ELECTRICITY**
GENERATED BY RENEWABLES[1]

**30%**
**OF HOT WATER**
HEATED WITH SOLAR[2]

## TECHNOLOGY

*What is the advantage of PV-T?*



**INCREASES PV PANEL EFFICIENCY**

BY LOWERING PV TEMPERATURE
CAPTURES HEAT FOR OTHER USES SUCH AS DOMESTIC HOT WATER

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** measured performance of a PV-T system provided by SunDrum Solar and installed at the O'Neill Federal Building in Boston, Massachusetts

## RESULTS

*How did PV-T perform in M&V?*

**1st**
LARGE-SCALE INSTALLATION; NUMEROUS LESSONS LEARNED[3]

**LIMITED**
COST-EFFECTIVE DEPLOYMENT POTENTIAL[4]

**COMPETITIVE**
WITH TRADITIONAL SOLAR WHEN 30-50% LESS EXPENSIVE[5]

### Energy Savings and Economics for PV-T

Cost-effective when electricity rates are high

| City | Electricity Rate ($/kWh) | City Cost Adjustment Multiplier | Solar Energy Production (kWh/yr) | Annual Cost Savings ($) | Installed Cost ($) | Simple Payback (yrs) | Payback with 30% Tax Credit (yrs) |
|---|---|---|---|---|---|---|---|
| Portland, OR | 0.09 | 0.992 | 6,698 | $581 | $56,765 | 98 | 68 |
| Boston, MA | 0.15 | 1.172 | 6,331 | $934 | $67,065 | 72 | 50 |
| Denver, CO | 0.11 | 0.943 | 11,063 | $1,198 | $53,961 | 45 | 32 |
| **Honolulu, HI** | **0.34** | **1.173** | **10,097** | **$3,488** | **$67,123** | **19** | **13** |
| Daggett, CA | 0.18 | 0.996 | 11,824 | $2,144 | $56,994 | 27 | 19 |
| Phoenix, AZ | 0.10 | 0.887 | 11,783 | $1,237 | $50,757 | 41 | 29 |

## DEPLOYMENT

*Where does M&V recommend deploying PV-T?*

**HIGH ELECTRIC RATES**

Small facilities, with electric rates > $.30 k/Wh, in hot climates with large domestic hot water (DHW) loads and limited roof space.

Incentives can lower system costs by as much as 75%

[1]Photovoltaic-Thermal New Technology Demonstration. Jesse Dean, Peter McNutt, Lars Lisell, Jay Burch, Dennis Jones, David Heinicke (NREL), January 2015 p.1 [2]Ibid, p.1 [3]Ibid, p.58 [4]Ibid, p.8 [5]Ibid, p.47

GPG FINDINGS

# 017

JANUARY 2015

# SOLAR-CONTROL FILMS

## OPPORTUNITY

*Windows in U.S. office buildings are responsible for how much cooling energy demand?*

**28%**

**OF COOLING ENERGY DEMAND IS DUE TO HEAT GAIN IN WINDOWS**[1]

**10 MILLION HOUSEHOLDS**

equivalent energy use[2]

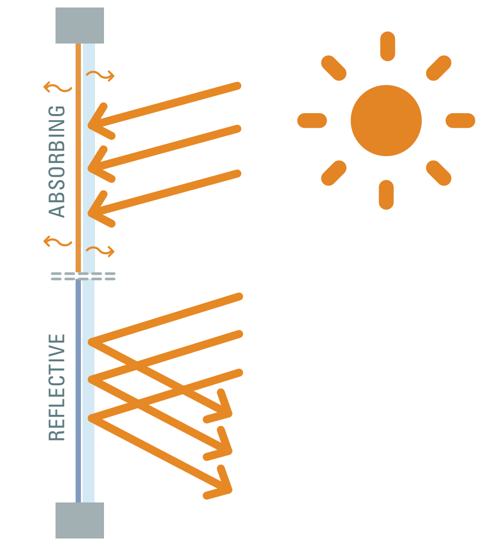
## TECHNOLOGY

*How do Applied Solar-Control Films work?*

**REDUCE HEAT GAIN**

BY ABSORBING OR REFLECTING SOLAR ENERGY

Spectrally-selective films affect only the infrared spectrum, with little impact on the visible appearance of glass




*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed a liquid-applied absorbing solar-control film provided by eTime Energy at the Goodfellow Federal Center in St. Louis, Missouri. They also modeled energy performance of both spectrally-selective absorbing and reflective films in warmer climates.

## RESULTS

*How did Applied Solar-Control Films perform in M&V?*

**GLAZING DEPENDENT**

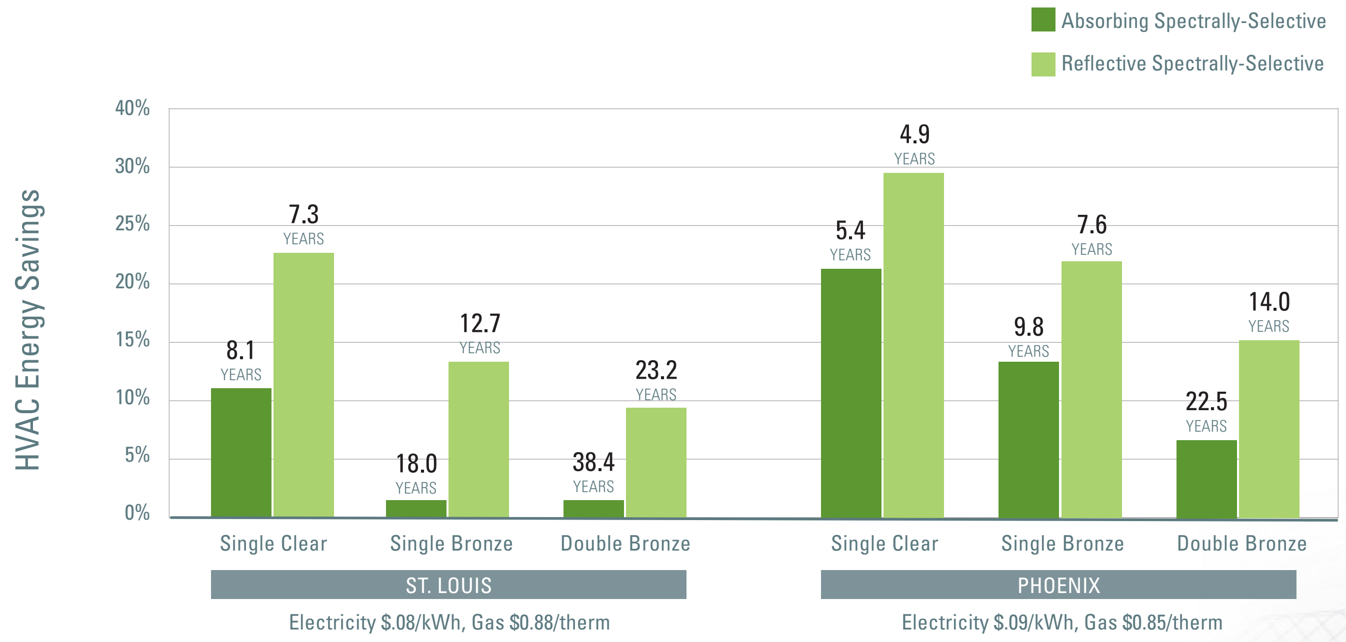
COST-EFFECTIVE FOR SINGLE-PANE CLEAR; NOT RECOMMENDED FOR DOUBLE-PANE BRONZE IN MOST CLIMATES[3]

**REFLECTIVE MORE EFFICIENT**

UP TO 29% HVAC ENERGY SAVINGS IN WARMER CLIMATES[4]

### Modeled Energy Savings For Range of Base Windows and Climates

Payback for liquid-applied absorbing @ $8/ft² (80% of current cost) and reflective @ $10/ft²




## DEPLOYMENT

*Where does M&V recommend deploying Applied Solar-Control Films?*

**SINGLE-PANE CLEAR WINDOWS**

Target buildings in climates with hot summers and mild winters, exposure to direct sun without exterior shading, and south, east or west orientations.

Reflective film is currently more cost-effective and more broadly recommended. Consider absorbing films for historic buildings where reflected solar radiation might damage exterior wood trim.

[1]Liquid-Applied Absorbing Window Film Retrofit, Charlie Curcija, Howdy Goudey, Robin Mitchell, Leandro Manes, Stephen Selkowitz, LBNL, November 2014, p. 10 [2]Ibid, p.10 [3]Ibid, p.9 [4]Ibid, p.54

GSA

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# 018 WEATHER STATION FOR IRRIGATION CONTROL

GPG FINDINGS

**JANUARY 2015**

## OPPORTUNITY

*What portion of water consumed by office buildings goes to irrigation?*

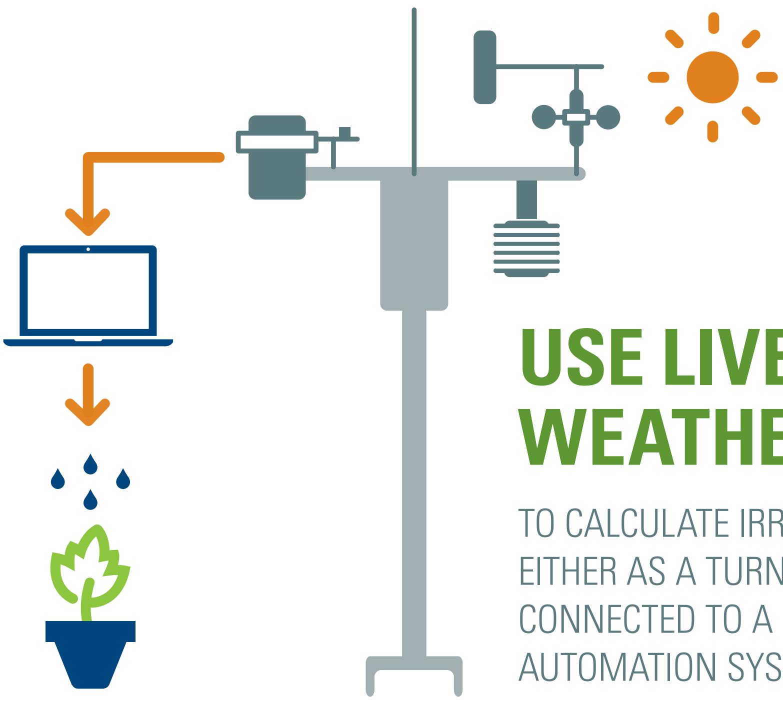
**20%**
**OF WATER IN U.S. OFFICE BUILDINGS IS USED FOR IRRIGATION**[1]

**UP TO 50% WASTED**
with timer-based irrigation[2]

**20-40% CAN BE SAVED**
with smart irrigation, depending on climate, soil, and vegetation profile[3]

## TECHNOLOGY

*How do Weather-Stations for Irrigation Control work?*



**USE LIVE LOCAL WEATHER DATA**

TO CALCULATE IRRIGATION NEEDS, EITHER AS A TURNKEY SYSTEM OR CONNECTED TO A BUILDING AUTOMATION SYSTEM (BAS)

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed a weather station provided by Campbell Scientific and connected to a BAS at the Hart-Dole-Inouye Federal Center in Battle Creek, Michigan.

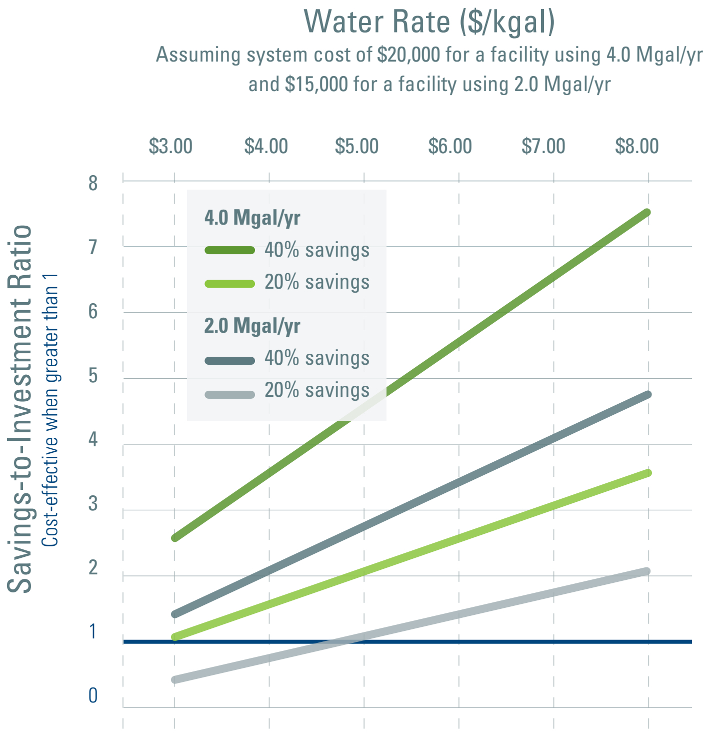
## RESULTS

*How did Weather-Stations for Irrigation Control perform in M&V?*

**66%**
**WATER SAVINGS**
PROJECTED[4]

**BAS-CONNECTED**
**WEATHER STATION**
CHALLENGING TO PROGRAM AND NOT FULLY REALIZED, TURNKEY RECOMMENDED AT PRESENT[5]

### Life-Cycle Cost Analysis for Smart-Irrigation Systems





## DEPLOYMENT

*Where does M&V recommend deploying Weather-Stations for Irrigation Control?*

**FURTHER RESEARCH**
**CONNECTING WEATHER STATIONS TO BAS NEEDS MORE SUPPORT**
Meanwhile, turnkey weather-based systems recommended.* Areas with intermittent rain will have higher savings and should be targeted first.

[1]Assessment of Weather Station Used for Irrigation Control: Hart-Dole-Inouye FederalCenter, Battle Creek, MI, KL McMordie Stoughton, RS Butner, PNNL, November 2014, p. 3 [2]Ibid, p.3 [3]Ibid, p.3 [4]Ibid, p.6 [5]Ibid, p.10 Subject to evaluation and approval by GSA-IT and Security

FEBRUARY 2015

# CATALYST-BASED SCALE PREVENTION

## OPPORTUNITY

*What percentage of the U.S. has hard water?*

**85%**

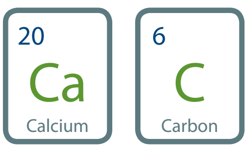
**OF THE UNITED STATES HAS HARD (>121 MG/L) WATER[1]**

**CALCITE BUILDUP**

due to hard water restricts water flow and causes heating systems to overheat and fail

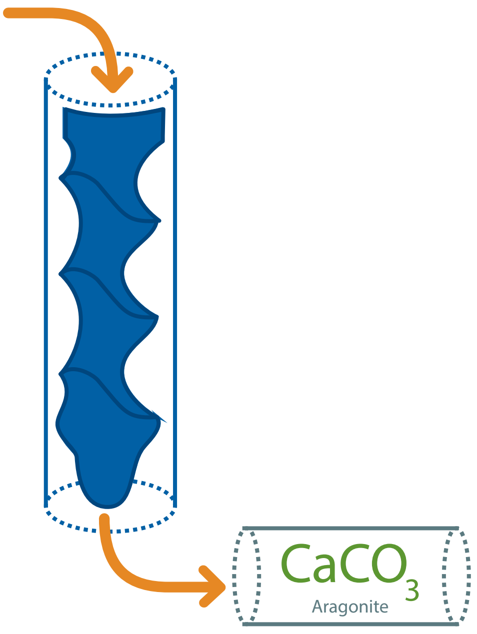
## TECHNOLOGY

*How does Non-Chemical Scale Prevention work?*




**PIPE WITH HELICAL INSERT PREVENTS CALCITE BUILDUP**

BY TRANSFORMING CALCIUM AND CARBON TO FLUSHABLE ARAGONITE CRYSTALS




## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** assessed the effectiveness of catalyst-based non-chemical scale prevention provided by Fluid Dynamics at the Moss Federal Courthouse in Salt Lake City, Utah. Before installation of the technology, commercial-grade heating elements overheated and failed after only two months of operation.

## RESULTS

*How did Non-Chemical Scale Prevention perform in M&V?*

**EFFECTIVE**

**REDUCTION OF CALCITE**

NO BUILDUP AFTER 18 MONTHS[2]

**O&M**

**MINIMAL**

NO MOVING PARTS OR CHEMICALS[3]

**<2 yrs**

PAYBACK; IMMEDIATE WHEN COMPARED TO CHEMICAL SYSTEMS[4]

### Non-Chemical Scale Prevention vs. Salt-Based System in Salt Lake City

Payback for catalyst-based non-chemical scale prevention is immediate compared to a salt-based system

| | Salt-Based System | Catalyst-Based Non-Chemical Scale Prevention |
|---|---|---|
| Equipment Cost | **$2,600** | **$1,192— 3/4" diameter unit** Unit pricing ranges between $798 for a 3/8" pipe and $96,360 for a 16" pipe. |
| Installation Cost | **$600** | **$500 —10 hours @ $50/hr** Installation for new construction is $0, as it incurs no additional costs over baseline. |
| Maintenance Costs/year | **$1,850—$350 chemicals, $1,500 labor** | **$100—biannual tank cleaning** Required in systems without a drain. |
| Simple Payback | | **Immediate** |

## DEPLOYMENT

*Where does M&V recommend deploying Non-Chemical Scale Prevention?*

**FACILITIES WITH HARD WATER**

Any heating system with calcification issues including hydronic heating systems and boilers, condensing boilers, and gas and electric water heaters. The harder the water, the more likely non-chemical sacle prevention will be cost-effective

[1]American Water Works Association, Public Notice Article, May 2007 [2]Catalyst-Based Non-Chemical Water Treatment System, Frank E. Moss U.S. Courthouse, Salt Lake City, Utah, Dan Howett (ORNL) October 2014, p.1 [3]Ibid, p.24 [4]Ibid, p.25

GPG FINDINGS **020**

MARCH 2015

# WIRELESS THERMOSTATS FOR PNEUMATIC SYSTEMS

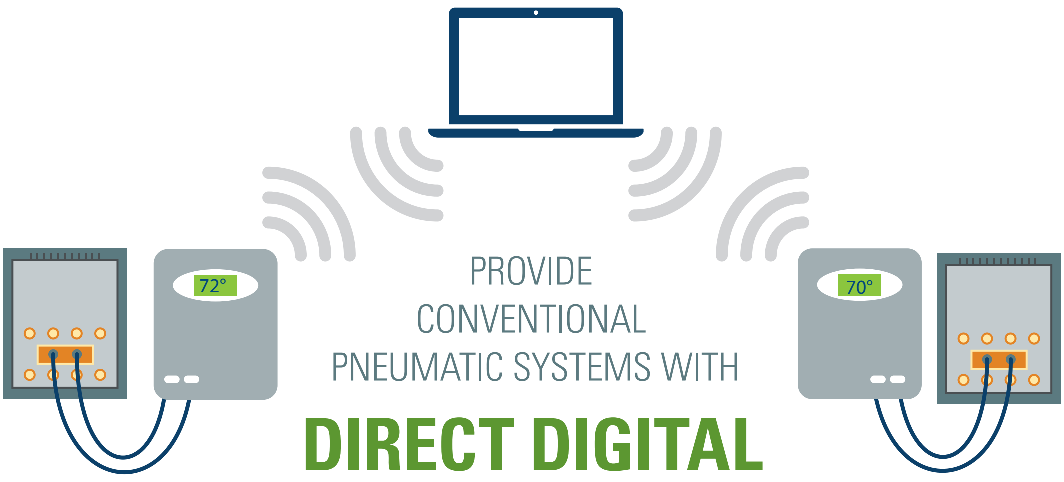
## OPPORTUNITY

*Where are pneumatic thermostats typically found?*

**COMMERCIAL BUILDINGS BUILT BEFORE 1999** that are > 20,000 ft² and multi-story[1]

## TECHNOLOGY

*How do Wireless Pneumatic Thermostats work?*




PROVIDE CONVENTIONAL PNEUMATIC SYSTEMS WITH

**DIRECT DIGITAL CONTROL (DDC) FUNCTIONALITY**

## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** assessed wireless pneumatic thermostats provided by Cypress Envirosystems at the Woodrow Wilson International Center for Scholars in Washington, DC

## RESULTS

*How did Wireless Pneumatic Thermostats perform in M&V?*

**EFFECTIVE APPLICATION** OF ENERGY-SAVING CONTROL STRATEGIES[2]

**ENERGY SAVINGS** ACROSS CLIMATE ZONES AND OFFICE SIZES[3]

**<2-6 YRS PAYBACK** WITH UNOCCUPIED/ OCCUPIED CONTROL STRATEGY AND LOW INSTALLATION COSTS[4]

### Modeled Payback for Unoccupied/Occupied Control Strategy

Payback assumes an unoccupied setback of 83° for cooling and 62° for heating

| Location | | Large Office - 498,500 ft² Payback (years) | | Medium Office - 53,630 ft² Payback (years) | | Small Office - 5,500 ft² Payback (years) | |
|---|---|---|---|---|---|---|---|
| CLIMATE ZONE | CITY | LOW[1] | HIGH[2] | LOW[3] | HIGH[4] | LOW[5] | HIGH[6] |
| 1A | Miami, FL | 3.6 | 6.5 | 3.7 | 6.8 | 1.9 | 3.3 |
| 2A | Houston, TX | 3.7 | 6.7 | 4.5 | 8.2 | 2.9 | 5.0 |
| 2B | Phoenix, AZ | 4.6 | 8.2 | 4.0 | 7.3 | 2.5 | 4.3 |
| 3A | Atlanta, GA | 3.0 | 5.4 | 3.5 | 6.4 | 2.6 | 4.5 |
| 3B-coast | Los Angeles, CA | 2.8 | 5.1 | 3.7 | 6.8 | 3.7 | 6.3 |
| 3B | Las Vegas, NV | 5.3 | 9.5 | 5.0 | 9.2 | 3.1 | 5.4 |
| 3C | San Francisco, CA | 3.0 | 5.5 | 3.8 | 7.0 | 3.2 | 5.5 |
| 4A | Baltimore, MD | 2.8 | 5.0 | 3.3 | 6.0 | 2.7 | 4.7 |
| 4B | Albuquerque, NM | 5.4 | 9.7 | 6.0 | 10.9 | 3.5 | 5.9 |
| 4C | Seattle, WA | 3.6 | 6.5 | 4.5 | 8.2 | 4.3 | 7.4 |
| 5A | Chicago, IL | 3.1 | 5.6 | 3.8 | 7.0 | 2.8 | 4.8 |
| 5B | Boulder, CO | 5.0 | 8.9 | 5.7 | 10.5 | 3.7 | 6.4 |
| 6A | Minneapolis, MN | 4.6 | 8.3 | 5.7 | 10.5 | 3.7 | 6.3 |
| 6B | Helena, MT | 3.9 | 7.1 | 4.6 | 8.4 | 3.3 | 5.7 |
| 7 | Duluth, MN | 4.3 | 7.8 | 5.3 | 9.7 | 3.7 | 6.3 |
| 8 | Fairbanks, AK | 4.2 | 7.6 | 5.2 | 9.5 | 3.1 | 5.3 |

**Installation Costs:** [1] $0.50/ft² [2] $0.90/ft² [3] $0.60/ft² [4] $1.10/ft² [5] $0.70/ft² [6] $1.20/ft²

## DEPLOYMENT

*Where does M&V recommend deploying Wireless Pneumatic Thermostats?*

**ANY FACILITY**

**WITH CONVENTIONAL PNEUMATIC CONTROLS***

Deployment priority should be given to facilities with high energy costs

[1]Wireless Pneumatic Thermostat Evaluation, Ronald Reagan Building and International Trade Center, Washington, DC, Dan Howett, P.E., Mahabir Bhandari, PhD ORNL, March 2015, p. 2 [2]Ibid, p.3 [3]Ibid, p.4 [4]Ibid, p.4 *Subject to evaluation and approval by GSA-IT and Security

GPG FINDINGS

# 021

APRIL 2015

# WIRELESS SOIL-MOISTURE SENSORS FOR IRRIGATION CONTROL

## OPPORTUNITY

*What is the federally mandated water reduction goal?*

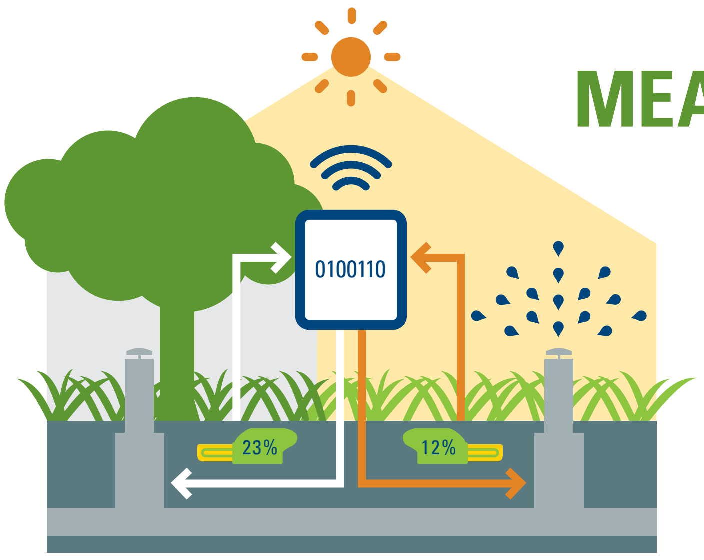
**36%**
**REDUCTION IN POTABLE WATER USE**
by 2025, compared to 2007 baseline[1]

**37% OF UNITED STATES**
is experiencing drought conditions[2]

**20-40% WATER SAVINGS**
with smart irrigation[3]

## TECHNOLOGY

*How do Wireless Moisture Sensors work?*




**MEASURE SOIL MOISTURE**

TO CALCULATE IRRIGATION NEEDS, AND TRANSMIT DATA TO CENTRAL IRRIGATION CONTROLLER

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed a ore-commercial implementation of wireless soil-moisture sensors for irrigation control provided by UgMo at the Young Federal Building in Orlando, Florida.

## RESULTS

*How did Wireless Moisture Sensors perform in M&V?*

**INCONCLUSIVE**
**RESULTS**

COMMUNICATION AND SENSOR PROBLEMS OF PRE-COMMERCIAL TECHNOLOGY COMPROMISED ANALYSIS[4]

Product development continued after M&V

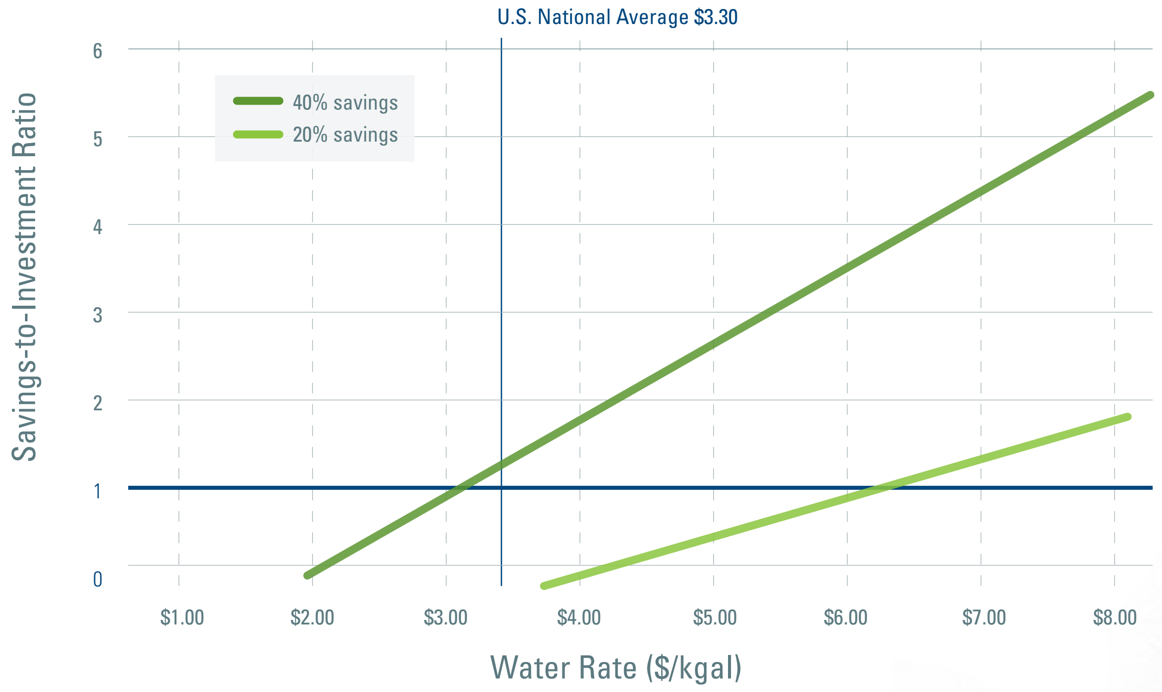
**GREATER**
**GRANULARITY**

THAN WEATHER-BASED IRRIGATION CONTROL OFFERS POTENTIAL FOR GREATER SAVINGS[5]

### Economic Assessment for Soil-Moisture Sensor Installation in Orlando

Cost-effective when Savings-to-Investment Ratio (SIR) is greater than 1

Assuming installed system cost of $4,500, annual costs of $680 and 773,700 gal/yr water use




## DEPLOYMENT

*Where does M&V recommend deploying Wireless Moisture Sensors?*

**FURTHER RESEARCH**
**DOCUMENTING SENSOR EFFECTIVENESS**

Meanwhile, turnkey weather-based controllers are recommended*

[1]Executive Order 13693, https://www.whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade [2] *The New York Times*, Mapping the Spread of Drought Across the U.S., Accessed 4/6/2015. [3]Irrigation Controls Based on Wireless Soil Moisture Technology Assessment: George C. Young Federal Building and U.S. Courthouse, Orlando, FL, KL McMordie Stoughton, RS Butner, PNNL, March 2015, p. 1 [4]Ibid, p.1 [5]Ibid, p.3 *Subject to evaluation and approval by GSA-IT and Security

GPG FINDINGS

# 022

MAY 2015

# WIRELESS ADVANCED LIGHTING CONTROLS

## OPPORTUNITY

*How much energy is used for lighting in U.S. commercial buildings?*

**26%**

**OF ELECTRICITY**

GOES TO LIGHTING[1]

**>30%**

**DEMONSTRATED SAVINGS**

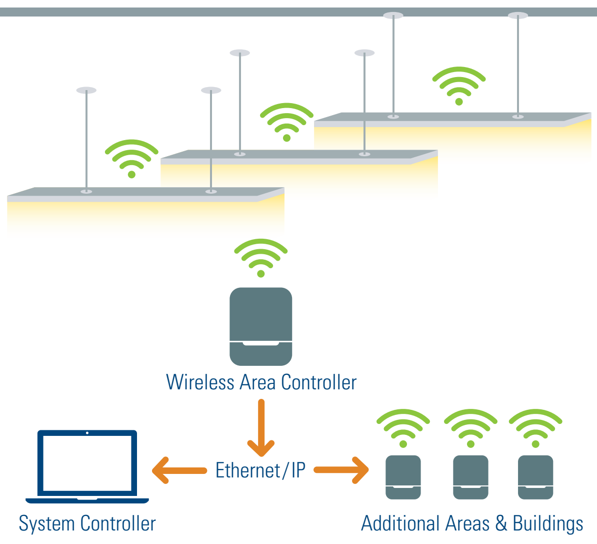
WITH ADVANCED LIGHTING CONTROLS (ALC)[2]

Compared to national average EUI of 4.1 kWh/ft²/yr

**ONLY 2% OF U.S. COMMERCIAL BUILDINGS IMPLEMENT ALC[3]**

## TECHNOLOGY

*How do Wireless Advanced Lighting Controls work?*




**WIRELESS NETWORKING**

ENABLES ALC FUNCTIONALITY WITHOUT THE EXPENSE OF INSTALLING DEDICATED CONTROL WIRING

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed wireless advanced lighting controls provided by Daintree with new fluorescent lamps and dimmable ballasts at the Moss Federal Building in Sacramento, California, and with LED fixtures at the Appraisers Building in San Francisco.

## RESULTS

*How did Wireless Advanced Lighting Controls perform in M&V?*

**54%**

**SAVINGS**

78% SAVINGS INCLUDING LED[4]

Normalized for GSA

**INCREASED**

**FLEXIBILITY**

IN LIGHT LEVELS TO SUIT USER PREFERENCES[5]

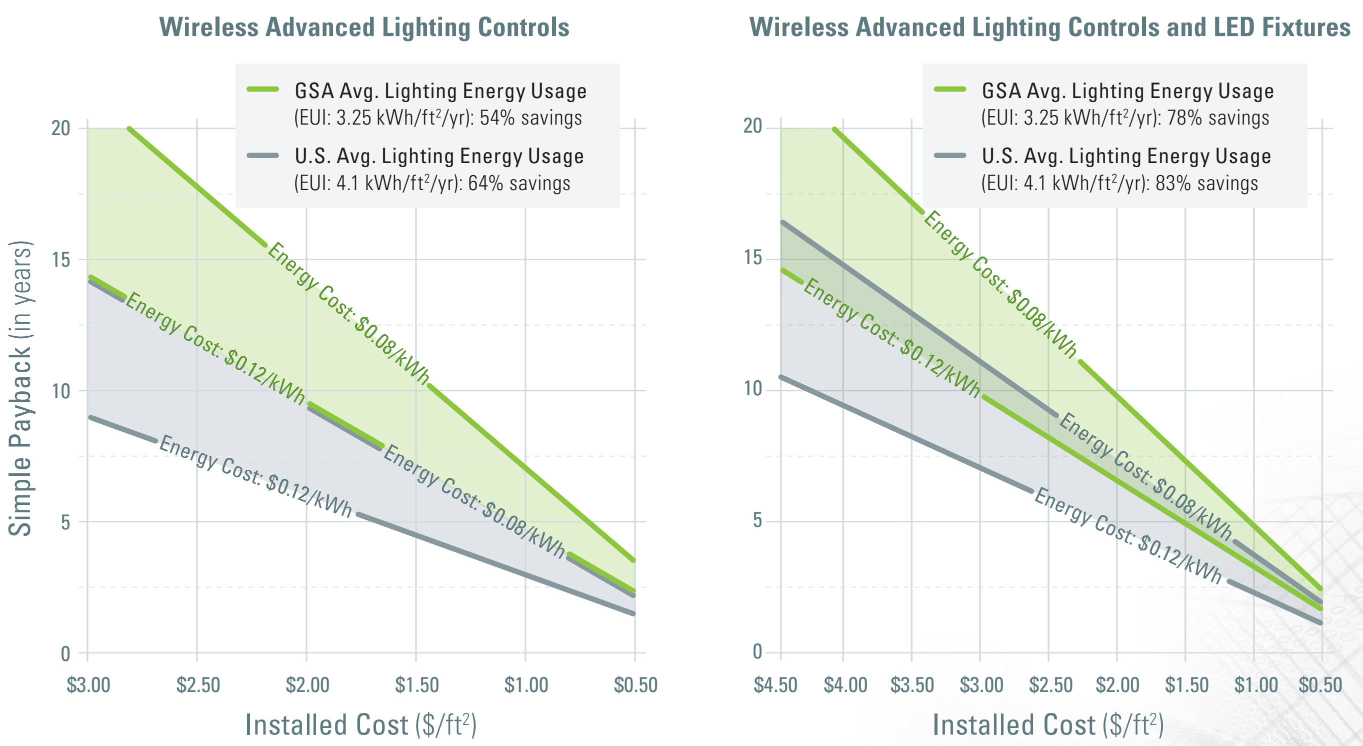
**3-6 yr**

**INCREMENTAL PAYBACK**

FOR RENOVATIONS[6]

### Payback for Advanced Lighting Controls

Savings are heavily dependent on baseline conditions




## DEPLOYMENT

*Where does M&V recommend deploying Wireless Advanced Lighting Controls?*

**INTEGRATE WITH LED FOR RENOVATIONS**

Also consider for retrofits, targeting facilities with minimal lighting controls, high lighting energy use (EUI > 3.25 kWh/ft²/yr) and utility rates > $.10 kWh*

[1] Wireless Advanced Lighting Controls Retrofit Demonstration. Francis Rubinstein (LBNL), April 2015, p.7 [2] Ibid, p.23 [3] Ibid, p.23 [4] Ibid, p.7,39 [5] Ibid, p.7,39 [6] Ibid, p.7,39 *Subject to evaluation and approval by GSA-IT and Security

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg

GPG FINDINGS **023**

MAY 2015

# ELECTROCHROMIC WINDOWS FOR LAND PORTS OF ENTRY

## OPPORTUNITY

*What is the potential benefit to Land Ports of Entry?*

**PROVIDE DIRECT LINE OF SIGHT**

AN UNINTERRUPTED VISUAL PATH BETWEEN THE OBSERVER AND THE AREA UNDER SURVEILLANCE

## TECHNOLOGY

*How do electrochromic (EC) windows work?*

**TRANSITION FROM CLEAR TO DARK**

USING PHOTOSENSOR READINGS AND SUN PATH CALCULATIONS

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** measured glare reduction and occupant satisfaction with electrochromic windows provided by SageGlass at the Donna Land Port of Entry along the Texas border with Mexico.

## RESULTS

*How did electrochromic windows perform in M&V?*

**GLARE REDUCTION**

BELOW PERCEPTIBLE GLARE THRESHOLD[2]

**NIGHTTIME VISIBILITY REDUCED**

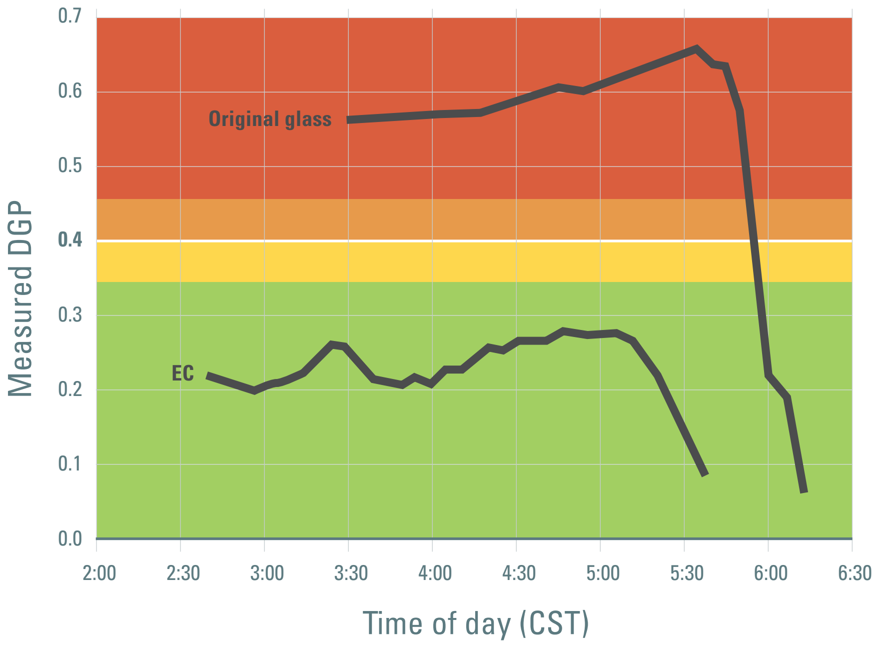
WITH INCREASED INTERIOR REFLECTION[3]

**100% USER PREFERENCE**

OVER CONVENTIONAL WINDOWS[4]

### Daylight Glare Probability (DGP) in Vehicle Inspection Booths Facing West

Booth with EC windows has much lower glare throughout a sunny afternoon




| DGP | Qualitative Interpretation |
|---|---|
| > 0.45 | Intolerable glare |
| 0.40 to 0.45 | Disturbing glare |
| 0.35 to 0.40 | Perceptible glare |
| < 0.35 | Imperceptible glare |

DGP is a metric for visual comfort, with values from 0 to 1, representing the probability that a person would experience disturbing glare in a particular situation.

## DEPLOYMENT

*Where does M&V recommend deploying electrochromic windows?*

**LAND PORTS OF ENTRY**

And other facilities where window glare compromises mission-critical outdoor visibility*

[1]Electrochromic Window Demonstration at the Donna Land Port of Entry. Eleanor S. Lee (LBNL), May 2015, p.4 [2]Ibid, p.43 [3]Ibid, p.4 *Subject to evaluation and approval by GSA-IT and Security

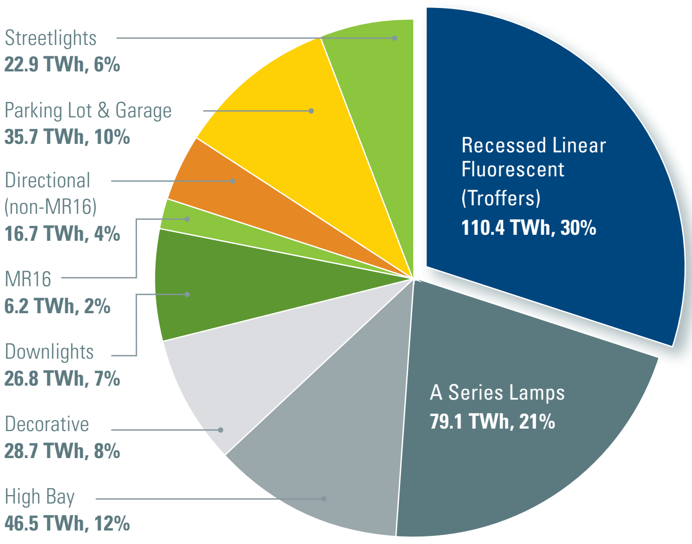
GPG FINDINGS 024

AUGUST 2015

# LED FIXTURES WITH INTEGRATED ADVANCED LIGHTING CONTROLS

## OPPORTUNITY

*How much energy could be saved annually in the U.S. by converting recessed linear fluorescents to LED?*




**110.4**

**TWh SAVED**[1]

EQUIVALENT TO 10 MILLION HOMES

1 TWh = average annual energy use of approximately 92,000 U.S. households

## TECHNOLOGY

*How do LED Fixtures with Integrated Controls work?*

### LED FIXTURES WITH ONBOARD SENSORS DYNAMICALLY MANAGE LIGHTING

USING OCCUPANCY SENSING AND DAYLIGHT HARVESTING; INTEGRATED CONTROLS REDUCE COMPLEXITY OF INSTALLATION AND SETUP

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed plug-and-play LED fixtures with Advanced Lighting Controls (ALC) provided by Philips Lighting at the Ralph H. Metcalfe Federal Building in Chicago and the Peachtree Summit Federal Building in Atlanta.

## RESULTS

*How did LED Fixtures with Integrated Controls perform in M&V?*

**69%**

**ENERGY SAVINGS**

OVER GSA AVERAGE

41% from LED
28% from ALC[2]

**40%**

**RETURN ON INVESTMENT**

FOR GSA RETROFITS

1.4 SIR at current estimated cost and utility rate of $.10 kWh[3]

**25%**

**OF COST SAVINGS**

DUE TO REDUCED MAINTENANCE

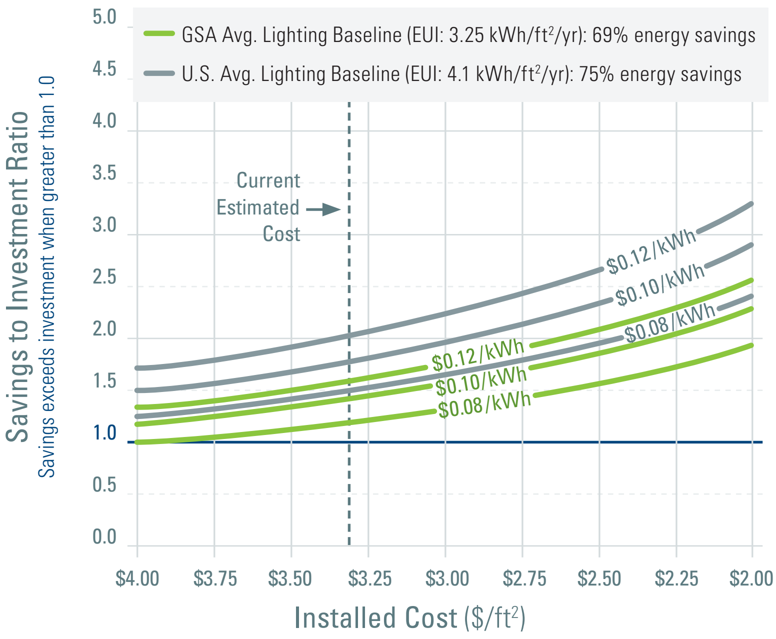
LEDs last twice as long as fluorescent lamps[4]

### Positive Return on Investment for Both Retrofits and Renovations

Retrofit SIR

Current cost with GSA average lighting use and $.10/kWh

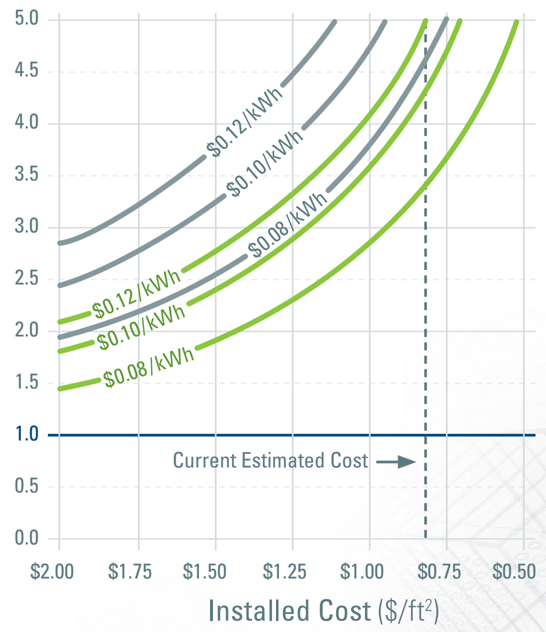
1.4 SIR—savings exceeds investment by 40%




Renovation and New Construction SIR

Current cost with GSA average lighting use and $.10/kWh

4.4 SIR—savings exceeds investment by 340%




## DEPLOYMENT

*Where does M&V recommend deploying LED Fixtures with Integrated Controls?**

### RECOMMENDED FOR RENOVATIONS

Consider for retrofits; prioritize facilities with minimal lighting controls, lighting energy use > 3.25 kWh/ft²/yr and utility rates > $.10/kWh (national average)

[1]Navigant Consulting Inc. April 2013 (Revised May 2013). *Adoption of Light-Emitting Diodes in Common Lighting Applications.*
[2]*Retrofit Demonstration of LED Fixtures with Integrated Sensors and Controls*, Francis Rubinstein (LBNL), July 2015, p.77 [3]Ibid, p.16
[4]Ibid, p.18 *Subject to evaluation and approval by GSA-IT and Security.

DECEMBER 2015

# SOCIALLY DRIVEN HVAC FOR PERSONAL CONTROL

## OPPORTUNITY

*How is temperature typically controlled in commercial buildings?*

### SET TO A PREDETERMINED RANGE OR "DEADBAND"

Does not account for individual thermal preferences
Wastes energy by over-conditioning, particularly in unoccupied spaces

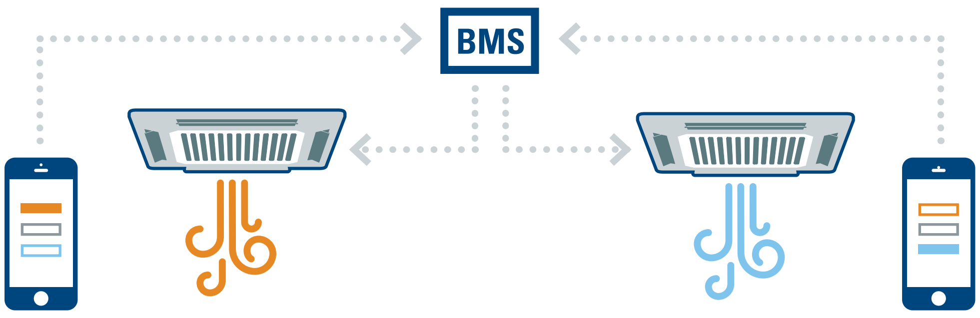
## TECHNOLOGY

*How does Socially Driven HVAC Optimization work?*

### USES DIRECT INPUT FROM OCCUPANTS IN TEMPERATURE MANAGEMENT

TRACKS USER PREFERENCES OVER TIME, FINE-TUNES THE DEADBAND

Optimizes energy savings by widening the deadband when there is no occupant input




## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** assessed socially driven HVAC optimization provided by Building Robotics at the Federal Building and U.S. Courthouse in Phoenix, Arizona

## RESULTS

*How did Socially Driven HVAC Optimization perform in M&V?*

**20%**
**COOLING ENERGY SAVINGS**
47% HEATING SAVINGS
Over typical GSA facility[1]

**59%**
**REDUCTION**
IN HOT AND COLD CALLS[2]

**83%**
**OCCUPANTS**
MORE SATISFIED WITH THERMAL CONDITIONS[3]

### Modeling Demonstrates Energy Cost Savings per Square Foot[§]

Calculations do not include O&M savings, energy savings from reducing the use of personal fans and heaters, or gains in occupant productivity that may result from increased thermal comfort

| Location | | Large Office - 498,500 ft² Cost Savings ($/ft²/yr) | | Medium Office - 53,630 ft² Cost Savings ($/ft²/yr) | | Small Office - 5,500 ft² Cost Savings ($/ft²/yr) | |
|---|---|---|---|---|---|---|---|
| CLIMATE ZONE | CITY | 2° Shift[1] | 4° Shift[2] | 2° Shift[1] | 4° Shift[2] | 2° Shift[1] | 4° Shift[2] |
| 1A | Miami, FL | $0.06 | $0.13 | $0.14 | $0.30 | $0.23 | $0.48 |
| 2A | Houston, TX | $0.06 | $0.12 | $0.10 | $0.20 | $0.16 | $0.32 |
| 2B | Phoenix, AZ | $0.07 | $0.13 | $0.12 | $0.24 | $0.18 | $0.38 |
| 3A | Atlanta, GA | $0.08 | $0.15 | $0.12 | $0.23 | $0.18 | $0.35 |
| 3B-coast | Los Angeles, CA | $0.11 | $0.15 | $0.15 | $0.27 | $0.22 | $0.50 |
| 3B | Las Vegas, NV | $0.06 | $0.15 | $0.09 | $0.21 | $0.16 | $0.29 |
| 3C | San Francisco, CA | $0.09 | $0.16 | $0.11 | $0.19 | $0.17 | $0.34 |
| 4A | Baltimore, MD | $0.09 | $0.16 | $0.12 | $0.22 | $0.15 | $0.30 |
| 4B | Albuquerque, NM | $0.05 | $0.10 | $0.08 | $0.15 | $0.13 | $0.27 |
| 4C | Seattle, WA | $0.09 | $0.16 | $0.10 | $0.16 | $0.12 | $0.18 |
| 5A | Chicago, IL | $0.06 | $0.10 | $0.07 | $0.12 | $0.10 | $0.19 |
| 5B | Boulder, CO | $0.06 | $0.10 | $0.07 | $0.13 | $0.11 | $0.18 |
| 6A | Minneapolis, MN | $0.05 | $0.09 | $0.06 | $0.11 | $0.10 | $0.18 |
| 6B | Helena, MT | $0.06 | $0.10 | $0.07 | $0.11 | $0.09 | $0.15 |
| 7 | Duluth, MN | $0.06 | $0.10 | $0.06 | $0.10 | $0.09 | $0.15 |
| 8 | Fairbanks, AK | $0.09 | $0.12 | $0.09 | $0.14 | $0.11 | $0.19 |

[§]Current socially driven HVAC subscription fees up to $0.60/ft²/yr, depending on installation size and duration of service [1] 70°-75° to 68°-77° [2] 70°-73° to 68°-77°

## DEPLOYMENT

*Where does M&V recommend deploying Socially Driven HVAC Optimization?**

### PRIORITIZE WHERE THERMAL COMFORT IS AN ISSUE

Savings will be greatest in facilities that are only intermittently occupied and have narrow deadbands and high energy costs

[1]*Socially Driven HVAC Optimization Federal Building and U.S. Courthouse Phoenix, Arizona*, Dan Howett (ORNL), October 2015, p. 17
[2]Ibid, p. 41 [3]Ibid, p. 22 *Subject to evaluation and approval by GSA-IT and Security.

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg

# GPG FINDINGS 026

APRIL 2016

# LED DOWNLIGHT LAMPS FOR CFL FIXTURES

## OPPORTUNITY

*How much energy could GSA save by converting CFL downlights to LED?*

**5.7 GWH OF ELECTRICITY PER YEAR**

If all 95,000 CFL-based downlights within the portfolio were replaced[1]

Annual savings of $600,000 at national average of $0.11/kWh

## TECHNOLOGY

*How do direct replacement LED downlight lamps work?*

**ONE-TO-ONE LAMP REPLACEMENT**

POWERED BY THE EXISTING CFL BALLAST

Light directed down toward living and work surfaces

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed LED downlight lamps provided by Lunera in three federal buildings: GSA 's regional headquarters in Auburn, Washington; the Cabell Federal Building in Dallas, Texas; and the Veterans Administration Center in Philadelphia, Pennsylvania

## RESULTS

*How did LED downlight lamps perform in M&V?*

**40-50%**
**ENERGY SAVINGS[2]**
$6.37 ANNUAL SAVINGS[3]
Over typical CFL lamp at avg. utility rate of $0.11/kWh

**LEDs**
**APPROXIMATED CFLS**
OCCUPANTS NOTICED LITTLE DIFFERENCE[4]

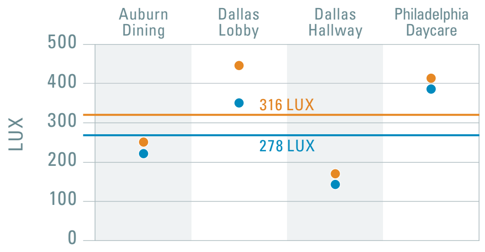
**< 3**
**YR PAYBACK**
AT AVERAGE UTILITY RATE[5]

### Light Levels Between CFL and LED Were Comparable

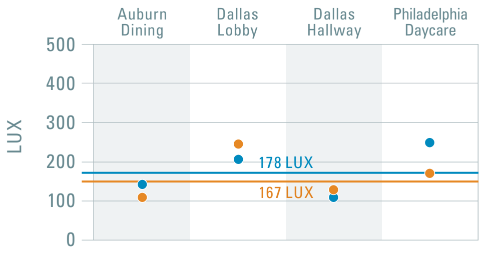
Key
- CFL
- CFL AVG. ACROSS TEST BEDS
- LED
- LED AVG. ACROSS TEST BEDS

A difference of less than 100 Lux is typically not noticeable by the human eye.

Average Horizontal Light Levels
Work Surface or Floor




Average Vertical Light Levels
Wall




## DEPLOYMENT

*Where does M&V recommend deploying LED downlight lamps?*

**DEPLOY BROADLY**

Where advanced lighting controls are not desired or useful

### LED Replacement Options for CFL Downlights

Consider compatibility and controls when selecting an LED replacement

| | REPLACE LAMP IF : | INSTALL RETROFIT KIT IF : | INSTALL NEW FIXTURE IF : |
|---|---|---|---|
| COMPATIBILITY | CFL ballast is verified to work with LED replacement lamp (per manufacturer or by testing). | Lamp is incompatible with CFL ballast (consult manufacturer specifications). | New construction or renovation. |
| CONTROLS | No controls are necessary. | Dimming is desired and CFL ballast does not support it. | Integrated advanced lighting controls are desired (tuning, occupancy sensing, daylighting). |
| | **PAYBACK–2.9 years*** Cost $39 Material $22§, Install $17 With ballast replacement $94 (Material $38, Install $56) PAYBACK 7.1 years | **PAYBACK –10.4 years*** Cost $137 Material $81, Install $56 | **PAYBACK–12.4 years*** Cost $165 Material $109, Install $56 |

*Assumes maintenance savings included; midrange material cost; RSMeans derived labor estimates; national average energy rate $0.11; 4000-hr/yr operation

§April 2016 — updated material cost of $15, provided by the vendor, reduces payback to 2.4 years

[1]*LED Downlight Lamps for CFL Fixtures*, EE Richman, JJ McCullough, TA Beeson, SA Loper (PNNL), March 2016, p.17 [2]Ibid, p.10 [3]Ibid, p.12 [4]Ibid, p.11 [5]Ibid, p.12

GPG FINDINGS 027

AUGUST 2016

# HONEYCOMB SOLAR THERMAL COLLECTOR

## OPPORTUNITY

*Why is GSA interested in the Honeycomb Solar Thermal Collector (HSTC)?*

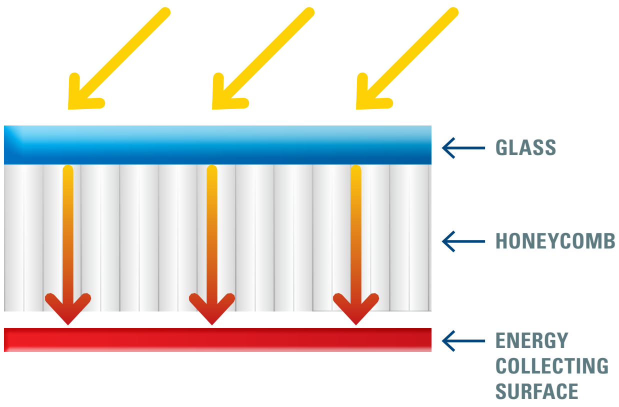
**30%** **SOLAR HOT WATER (SHW) REQUIRED**
TO COMPLY WITH EISA[1]

## TECHNOLOGY

*How does HSTC differ from typical flat-plate collectors?*

### MINIMIZES HEAT LOSS

Honeycomb insulating layer allows solar energy to enter the collector while reducing heat loss from the energy collecting surface




## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** measured performance of an HSTC system provided by Tigi Solar at two demonstration sites: the Major General Emmett J. Bean Federal Center in Indianapolis; and the GSA Regional Headquarters Building in Auburn, Washington

## RESULTS

*How did HSTC perform in M&V?*

### COMPARABLE

TO OTHER FLAT PLATES FOR STANDARD DHW

In SHW systems without a storage tank, HSTC should outperform other flat plates, particularly in cold climates[2]

### TRAINED

SHW INSTALLER IS CRITICAL

To address unique features of SHW systems[3]

### OVERHEATING PROTECTION WORKED

May decrease maintenance costs over time[4]

### Modeled Energy Savings for HSTC in Locations with Different Solar Resources

Large loads are critical for positive ROI

| City | Hot Water Load (gal/day) | System Unit Cost ($/ft$^2$) | Collector Area (ft$^2$) | Solar Fraction* | Annual Energy Savings (kWh/yr) | Payback (years) | SIR |
|---|---|---|---|---|---|---|---|
| **Seattle, WA cold/cloudy** annual solar radiation 5.0 gigajoule/m$^2$/yr | 125 | $102 | 88 | 0.44 | 3,154 | 40.0 | 0.26 |
| | 500 | $102 | 175 | 0.32 | 8,937 | 26.8 | 0.56 |
| | 500 | $46 | 175 | 0.32 | 8,937 | 13.0 | 1.15 |
| **Indianapolis, IN cold/partly cloudy** annual solar radiation 5.9 gigajoule/m$^2$/yr | 125 | $102 | 88 | 0.51 | 3,638 | 29.0 | 0.42 |
| | 500 | $102 | 175 | 0.38 | 10,448 | 19.2 | 0.81 |
| | 500 | $46 | 175 | 0.38 | 10,448 | 9.3 | 1.68 |
| **Denver, CO cold/sunny** annual solar radiation 6.8 gigajoule/m$^2$/yr | 125 | $102 | 88 | 0.60 | 4,291 | 24.5 | 0.54 |
| | 500 | $102 | 175 | 0.44 | 12,343 | 16.2 | 0.98 |
| | 500 | $46 | 175 | 0.44 | 12,343 | 7.8 | 2.03 |
| **Phoenix, AZ warm/sunny** annual solar radiation 8.5 gigajoule/m$^2$/yr | 125 | $102 | 88 | 0.54 | 2,757 | 21.4 | 0.50 |
| | 500 | $102 | 175 | 0.71 | 13,556 | 15.0 | 1.06 |
| | 500 | $46 | 175 | 0.71 | 13,556 | 7.3 | 2.20 |

* The solar fraction represents the fraction of the total hot water energy load that is displaced by the solar hot water system

## DEPLOYMENT

*Where does M&V recommend deploying SHW?*

### ELECTRIC WATER HEATERS LARGE CONSISTENT LOADS

Natural gas prices in the U.S. are generally too low to make SHW cost-effective. Life-cycle cost, rather than efficiency, should drive system selection.

[1] High Performance Flat Plate Solar Thermal Collector Evaluation. Caleb Rockenbaugh, Jesse Dean, David Lovullo, Lars Lisell, Greg Barker, Ed Hancock, Paul Norton (NREL), July 2016 p.8 [2] Ibid, p.7 [3] Ibid, p.11 [4] Ibid, p.8

GPG FINDINGS **028**

SEPTEMBER 2016

# CHILLER PLANT CONTROL OPTIMIZATION SYSTEM

## OPPORTUNITY

*What is the impact of improved chiller operations on GSA?*

**80% OF GSA FLOOR SPACE IS IN LARGE BUILDINGS**

The majority of which is cooled by chillers[1]

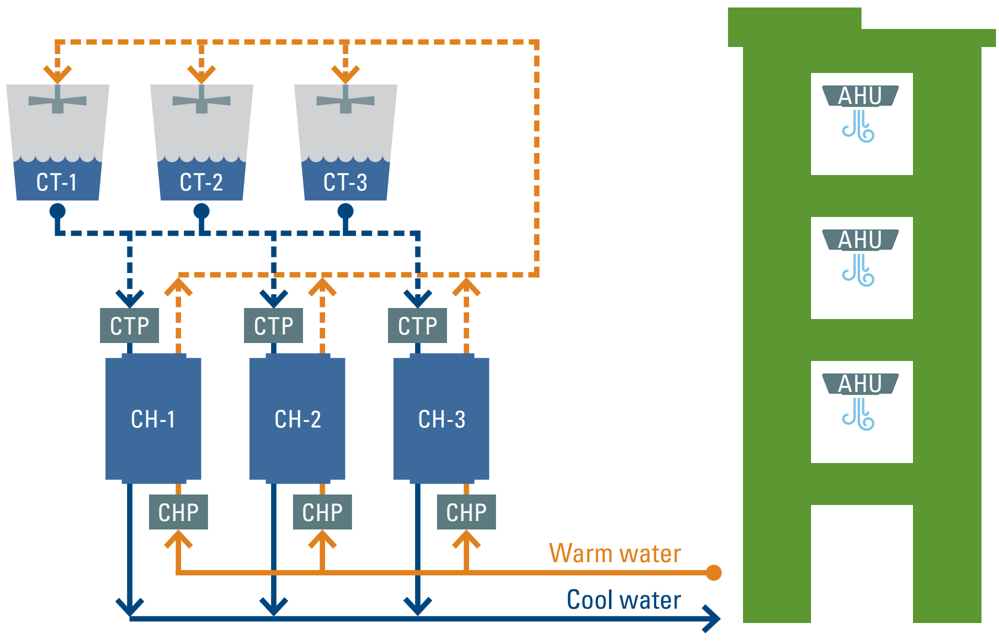
## TECHNOLOGY

*How does the Control Optimization System for Chiller Plants work?*

**OPTIMIZES SYSTEM PRESSURE AND TEMPERATURE DIFFERENCE (DELTA T)**

MANAGES CHILLER LIFT AND FLOW BY MONITORING AND CONTROLLING FIVE INTERDEPENDENT SYSTEMS

Cooling Towers (CT), Chillers (CH), Condenser Pumps (CTP), Chilled Water Pumps (CHP), and Air Handler Units (AHU)




## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed a control optimization system for chiller plants provided by Siemens at the Frank M. Johnson Jr. Federal Building and U.S. Courthouse in Montgomery, Alabama

## RESULTS

*How did the Control Optimization System perform in M&V?*

**35%** **COOLING SAVINGS**

+/- 10% uncertainty due to estimated baseline[1]

**5 YR** **PAYBACK**

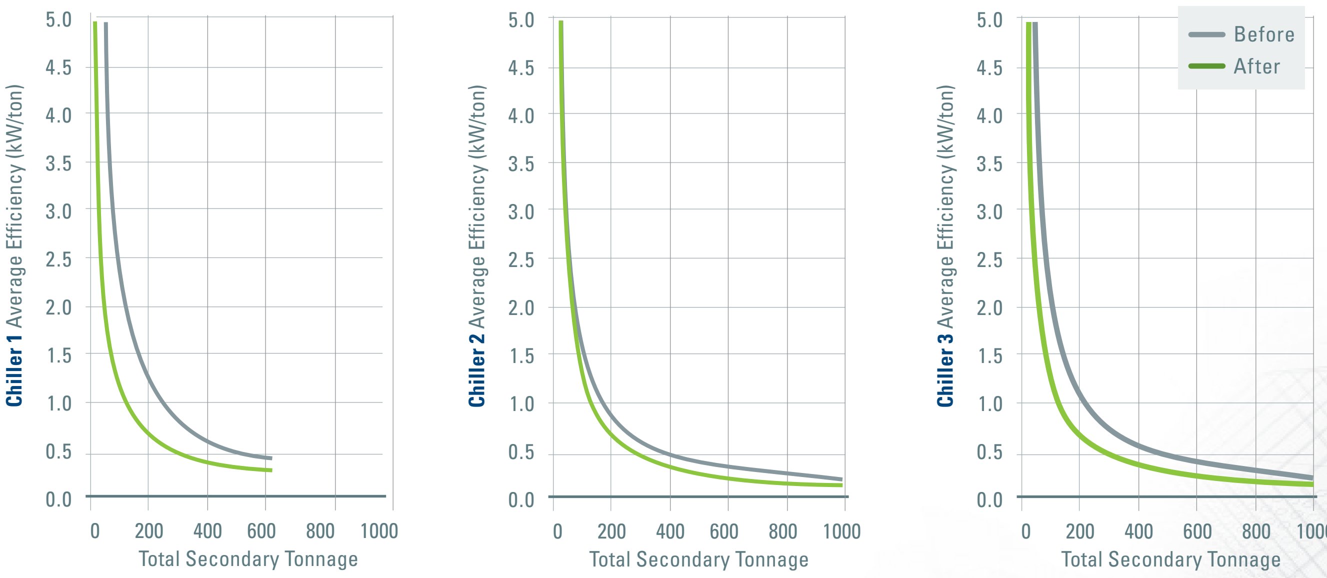
At avg. cost of $0.11/kWh[3]

**BETTER** **VISIBILITY & CONTROL**

FOR PLANT OPERATIONS[2]

### Increased Efficiency, Especially at Part Loads

Performance averaged 0.64 kW/ton after control optimization




## DEPLOYMENT

*Where does M&V recommend deploying the Control Optimization System?*

**CENTRIFUGAL CHILLERS WITH LOADS > 3 MILLION TON-HRS/YR**

Also consider for incorporation into new all-variable-speed chiller plants, where both installation costs and energy savings may be lower.

[1] *Optimization of Variable Speed Chiller Plants: Frank M. Johnson Jr. Federal Building and U.S. Courthouse, Montgomery, Alabama*, JC Hail, DD Hatley, RM Underhill (PNNL), August 2016, p.13 [2] Ibid, p.7 [3] Ibid, p.38 [4] Ibid, p.7

GPG FINDINGS

# 029

SEPTEMBER 2016

# SMART CEILING FANS

## OPPORTUNITY

*How much electricity could be saved by raising cooling setpoints across the GSA-owned portfolio?*

**18.7** **MILLION kWh ANNUALLY**

$2 MILLION @ GSA AVERAGE OF $0.11 kWh[1]

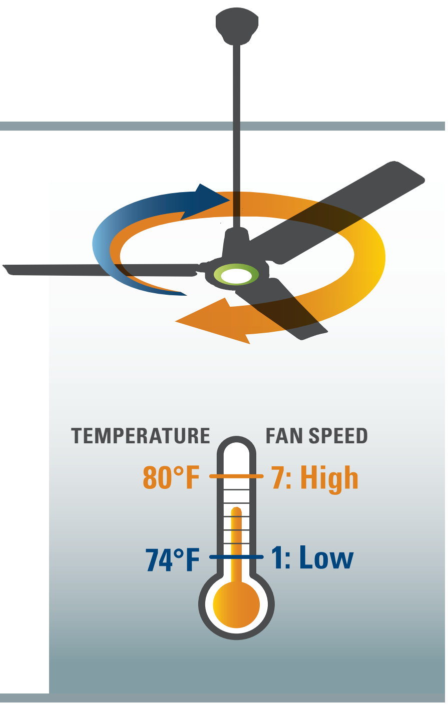
by raising cooling setpoints 2°F

## TECHNOLOGY

*How do Smart Ceiling Fans work?*

**SENSORS MEASURE TEMPERATURE AND INCREMENTALLY ADJUST FAN SPEED**

TURN ON AND OFF AUTOMATICALLY BASED ON OCCUPANCY OR PREDETERMINED TEMPERATURES




## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** modeled energy savings and assessed the deployment potential for ceiling fans provided by Big Ass Solutions

## RESULTS

*What did modeling of Smart Ceiling Fans reveal?*

**4-11%**

**ENERGY SAVINGS**

WITH 4°F SETPOINT INCREASE

From 74°F to 78°F[2]

**SAVINGS**

**GREATEST IN**

FIRST 4 DEGREES OF SETPOINT CHANGE[3]

**<$1.50/ft²**

**INSTALLED COST**

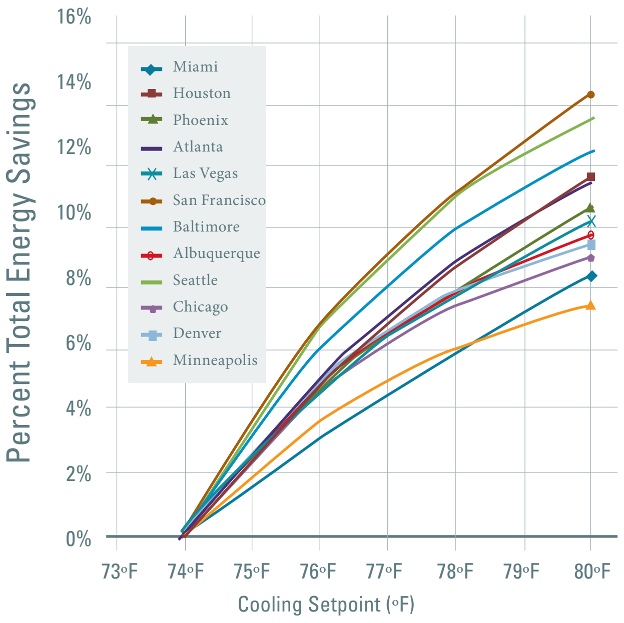
For < 10-year payback[4]

### Modeled Savings for Smart Fans

Energy savings for ENERGY STAR certified fans will be roughly equivalent

**Energy Savings Across Climate Zones**

Savings are greatest in San Francisco




**Installed Cost Needed for a 10-year Payback**

Assuming a 4°F increase in cooling setpoint

| Location | Energy Savings kWh/ft²/yr | Energy Cost Savings $/ft²/yr | Installed Cost for 10-year Payback $/ft² |
|---|---|---|---|
| Miami, FL | 1.19 | $0.117 | $1.17 |
| Houston, TX | 1.41 | $0.115 | $1.15 |
| Phoenix, AZ | 1.47 | $0.149 | $1.49 |
| Atlanta, GA | 1.26 | $0.131 | $1.31 |
| Las Vegas, NV | 1.26 | $0.119 | $1.19 |
| San Francisco, CA | 1.39 | $0.218 | $2.18 |
| Baltimore, MD | 1.26 | $0.140 | $1.40 |
| Albuquerque, NM | 1.02 | $0.105 | $1.05 |
| Seattle, WA | 1.19 | $0.095 | $0.95 |
| Chicago, IL | 0.81 | $0.075 | $0.75 |
| Denver, CO | 0.84 | $0.084 | $0.84 |
| Minneapolis, MN | 0.71 | $0.070 | $0.70 |

## DEPLOYMENT

*Where does the white paper recommend deploying Smart Ceiling Fans?*

**CONSIDER FOR OPEN OFFICES**

Target facilities with:

- Ceilings at least 9 feet high and interior/desk partitions less than 54 inches tall
- At least 2,000 cooling degree days and full daytime business hours
- No features, such as lighting or air conditioning, that will interfere with fan blades
- Cooling setpoint lower than 75°, and no prohibitions against raising it

[1] *GSA Green Proving Ground, Smart Ceiling Fan – White Paper,* K. Kiatreungwattana, M. Deru, J. DeGraw (NREL), August 2016, p.13
[2] Ibid, p.7 [3] Ibid, p.38 [4] Ibid, p.7

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg

# GPG FINDINGS 030

SEPTEMBER 2016

# TLED LIGHTING RETROFITS WITH DEDICATED DRIVERS

## OPPORTUNITY

*How much energy could GSA save by converting LFLs to LEDs?*

**134 GWH**
**ELECTRICITY/YEAR**

**REPLACING 1.53 MILLION LINEAR FLUORESCENT LAMPS (LFLS)**
**$15 MILLION ANNUAL SAVINGS**
at national average utility rate of $0.11/kWh[1]

## TECHNOLOGY

*How do these LED Retrofits work?*

**REPLACE LAMP AND LED DRIVER**

USING EXISTING LENS & FIXTURE; NO NEED TO ALTER CEILING GRID

Compatible with advanced lighting controls (ALCs)

## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** assessed two LED retrofits ("LED-A" and "LED-B") provided by NEXT Lighting and Cree in three federal buildings: GSA's regional headquarters in Auburn, Washington; the Cabell Federal Building in Dallas, Texas; and the Veterans Administration Center in Philadelphia, Pennsylvania

## RESULTS

*How did LED Retrofits perform in M&V?*

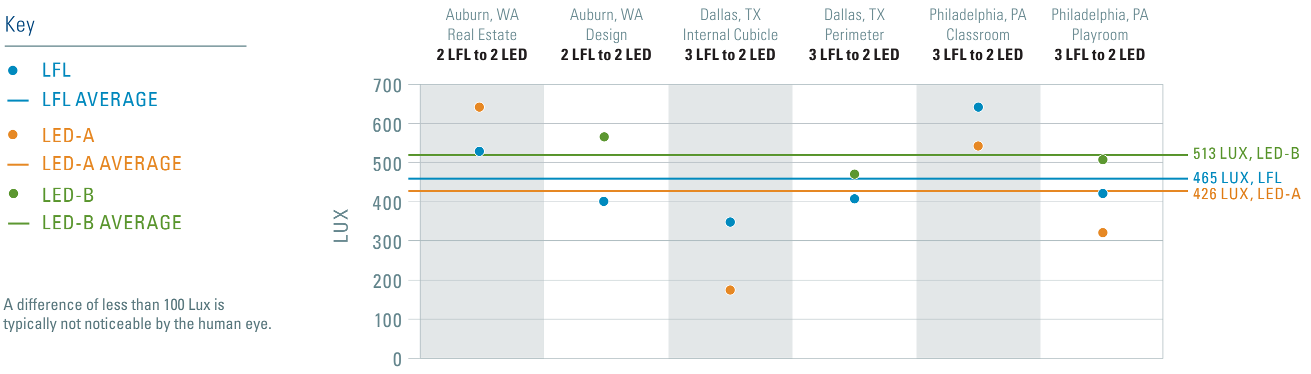
**27-29%**
**ENERGY SAVINGS[2]**
ADDITIONAL SAVINGS POSSIBLE WITH ALC

**EASY**
**INSTALLATION**
SIMILAR TO LFL LAMP AND BALLAST REPLACEMENT[3]

**6**
**YR PAYBACK**
AT NAT'L AVG. UTILITY RATE ($0.11/kWh) & $50 FIXTURE COST[4]

### Average Light Levels Across Test-Bed Sites

LED retrofits had similar illuminance levels but different light output (LED-A, 4500 lumens; LED-B, 4400 lumens)




## DEPLOYMENT

*Where does M&V recommend deploying LED Retrofits?*

**FIXTURES WITH LENSES AND SOCKETS IN GOOD CONDITION**

And where ALC is desired or useful. To assess fit, light levels, color temperature and glare, test a small number of lights before committing to purchase.

### LED Retrofit Options Assessed During M&V

Consider compatibility and controls when selecting an LED replacement

| | PROS | CONS | COST* |
|---|---|---|---|
| **LED-A**<br>**Replacement lamp uses alternative mounting, LED driver** | • Lamps can be repositioned in the fixture<br>• Dimming & ALC possible | • Performance depends on optics & lens of existing fixture<br>• Self-tapping screws could cause electrical problems<br>• Wire harnesses won't always fit legacy situations<br>• Not compatible with master/remote configurations or shunted lamp holders | **Equipment:**<br>$40–$70<br>**Installation:**<br>$34–$68 |
| **LED-B**<br>**Replacement lamp uses existing socket, LED driver** | • Familiar installation process<br>• Compatible with shunted and unshunted lamp holders<br>• Dimming & ALC possible | • Performance depends on optics & lens of existing fixture | **Equipment:**<br>$40–$70<br>**Installation:**<br>$34–$68 |

* 50% and 100% RS Means derived labor estimates; similar cost to lamp + ballast replacement

[1]*Linear LED Lighting Retrofit Assessment*, EE Richman, JJ McCullough, TA Beeson (PNNL), September, 2016, p.2 [2]Ibid, p.5
[3]Ibid, p.61 [4]Ibid, p.10

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg

GPG FINDINGS 031

UPDATED NOVEMBER 2017

# VARIABLE-SPEED DIRECT-DRIVE SCREW CHILLER

## OPPORTUNITY

*What is the impact of improved chiller operations on GSA?*

**MOST LARGE COMMERCIAL BUILDINGS (> 100,000 FT²) USE WATER-COOLED CHILLERS**

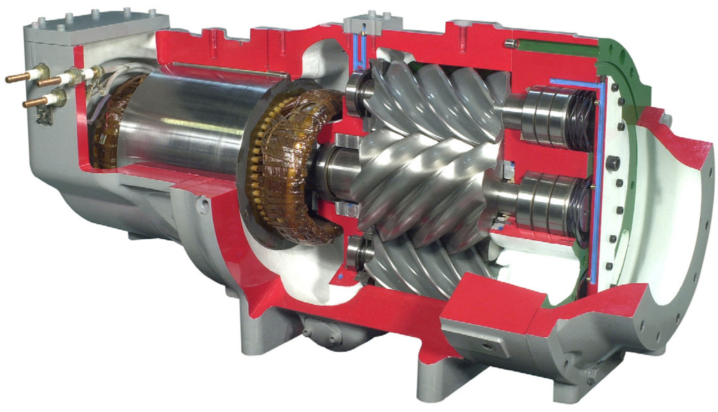
80% of GSA floor space is in large buildings[1]

## TECHNOLOGY

*How does this Variable-Speed Screw (VSS) Chiller work?*

**CAPACITY CONTROLLED BY REGULATING MOTOR SPEED ALONE**

THREE SCREW ROTORS AND A VARIABLE-SPEED MOTOR ARE THE ONLY MOVING PARTS; THERE ARE NO UNLOADERS[2]



## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** assessed a variable-speed direct-drive screw (VSS) chiller against a baseline variable-speed magnetic bearing chiller (MBC). The chillers were installed at the Sidney R. Yates Building in Washington, D.C. and connected to the same chilled water and condenser water loops, creating operating conditions as close to identical as possible within a real-world environment.

## RESULTS

*How did the Variable-Speed Screw Chiller perform in M&V at the test bed location?*

**High EFFICIENCY**

ENERGY PERFORMANCE COMPARED TO BASELINE MBC[3]

**Range OF OPERATING CONDITIONS MET**

Condenser water temperature ranged from 55°F to over 95°F[4]

**Quiet PERFORMANCE**

77-83 DECIBELS

For both VSS & MBC[5]

### Average Energy Consumption at the Yates Building

VSS savings over baseline MBC could range from +24% to -4% due to field measurement uncertainty[6]

| Combined Chillers/ Total Building % of full load | % of Full Year's Profile | VSS kW/ton (weighted) | MBC kW/ton (weighted) |
|---|---|---|---|
| 20-30% | 3.8% | 0.020 | 0.021 |
| 30-40% | 8.3% | 0.044 | 0.049 |
| 40-50% | 11.3% | 0.062 | 0.070 |
| 50-60% | 13.1% | 0.075 | 0.086 |
| 60-70% | 25.1% | 0.154 | 0.176 |
| 70-80% | 24.3% | 0.163 | 0.183 |
| 80-90% | 13.0% | 0.097 | 0.106 |
| 90-100% | 1.1% | 0.009 | 0.010 |
| | | **0.623** | **0.699** |

## DEPLOYMENT

*Where does M&V recommend deploying the Variable-Speed Screw Chiller?*

**CONSIDER VSS & MBC FOR END-OF-LIFE REPLACEMENT**

Both chillers performed effectively and have rated energy consumption that is more than 35% better than FEMP standards for water-cooled chillers. Individual site characteristics will determine the most cost-effective chiller for the application.

[1] *Variable-Speed Screw Chiller, Sidney Yates Building, Washington, DC,* Dan Howett (PE), Mark Adams (ORNL), George Ostrouchov PhD, revised August 2017, p.4 [2] Image courtesy of Carrier, used with permission [3] *Variable-Speed Screw Chiller, Sidney Yates Building, Washington, DC,* Dan Howett (PE), Mark Adams (ORNL), George Ostrouchov PhD, revised August 2017 p.3 [4] Ibid, p.186 [5] Ibid, p.25, 281 (as measured in a lab setting) [6] Ibid, p.9

GPG FINDINGS 032

FEBRUARY 2017

# LOW-E WINDOW FILM

## OPPORTUNITY

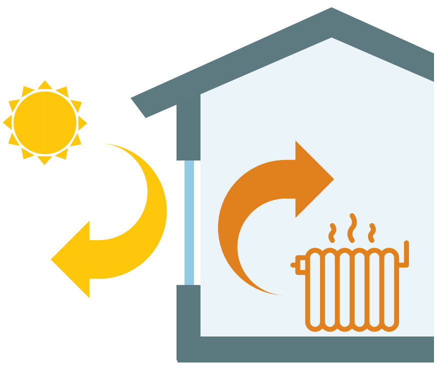
*Windows are responsible for how much energy use?*

**34%** OF COMMERCIAL BUILDING HVAC ENERGY IS LOST TO WINDOWS[1]

## TECHNOLOGY

*How does Low-e film work?*

### REDUCES SOLAR HEAT GAIN AND INSULATES



BY SELECTIVELY ABSORBING AND REFLECTING HEAT

Blocks direct solar heat to reduce summer cooling demand. Improves window insulation to reduce summer and winter energy use and improve occupant comfort.

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed a low-e film provided by the Eastman Chemical Company at two sites, the Hansen Federal Building in Ogden, Utah, and the Cabell Federal Building in Dallas, Texas. They also modeled energy performance in seven climates with four different base window configurations.

## RESULTS

*How did Low-e film perform in M&V?*

**29%** AVERAGE PERIMETER HVAC SAVINGS

with single-pane clear glass[2]

**BETTER** THERMAL COMFORT

Occupants reported superior comfort in both summer and winter[3]

**2-6 YR** PAYBACK

with single-pane glass; installed cost of $7.75 sq. ft.[4]

### Modeled Perimeter Energy Savings for Range of Climates

Whole building energy savings is estimated to be at least 1/3 of perimeter savings

| Location | | Single Clear Glazing to VT35 Film | | | Single Bronze Glazing to VT35 Film | | |
|---|---|---|---|---|---|---|---|
| CLIMATE ZONE | CITY | HEATING kBtu/ft2/yr | COOLING kBtu/ft2/yr | TOTAL % | HEATING kBtu/ft2/yr | COOLING kBtu/ft2/yr | TOTAL % |
| 1A | Miami, FL | 0.01 | 12.16 | 33% | 0.03 | 8.08 | 25% |
| 2A | Dallas, TX | 0.47 | 10.94 | 33% | 1.52 | 7.12 | 26% |
| 2B | Phoenix, AZ | 0.20 | 15.24 | 38% | 0.45 | 10.40 | 30% |
| 4A | Washington, D.C. | 0.51 | 6.40 | 26% | 3.24 | 3.74 | 23% |
| 5A | Chicago, IL | 1.97 | 5.66 | 24% | 5.79 | 3.23 | 22% |
| 5B | Ogden, UT | 1.45 | 7.13 | 30% | 4.97 | 4.12 | 27% |
| 6A | Minneapolis, MN | 2.97 | 5.45 | 22% | 7.51 | 3.06 | 21% |
| AVERAGE PERIMETER SAVINGS | | 1.08 | 9.00 | 29% | 3.36 | 5.68 | 25% |

## DEPLOYMENT

*Where does M&V recommend deploying Low-e Film?*

### ACROSS ALL CLIMATE ZONES

Biggest efficiency gain and fastest payback will be in buildings with either single glazing or existing applied film that is low performing or nearing the end of its (~15 year) service life.

Also consider for lower-performing double glazing that does not already have a low-e coating between panes.

[1]Low-e Applied Film Window Retrofit for Insulation and Solar Control, Charlie Curcija, Howdy Goudey, Robin Mitchell, LBNL, February 2017, p. 10 [2]Ibid, p. 62-131 [3]Ibid, p.43 [4]Ibid, p.42

GPG FINDINGS

# 033

NOVEMBER 2017

# ELECTROCHROMIC WINDOWS FOR OFFICE SPACE

## OPPORTUNITY

*What have previous studies demonstrated about the potential for electrochromic (EC) windows?*

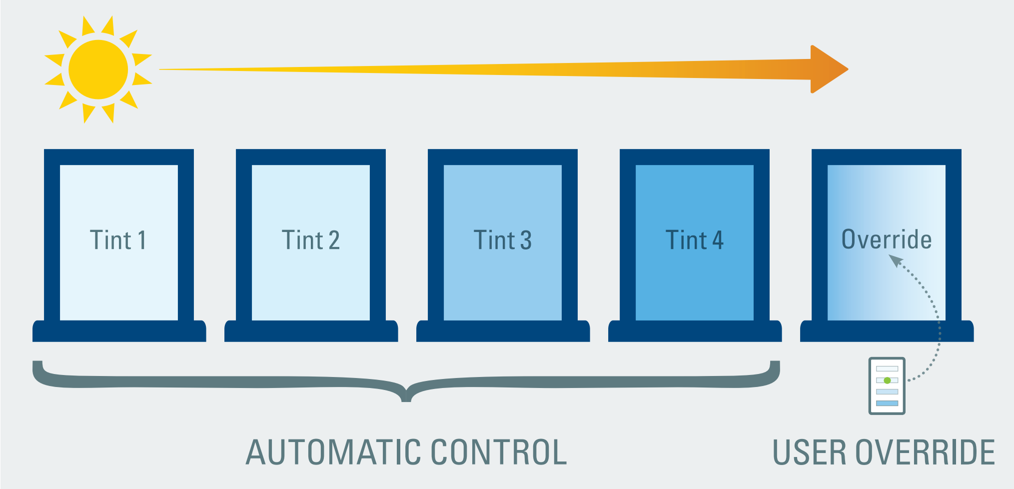
**REDUCED**

**— HEAT GAIN AND COOLING ENERGY[1]**
**— LIGHTING ENERGY[2]**
**— GLARE[3]**

## TECHNOLOGY

*How do EC windows work?*

**WINDOWS TINT IN RESPONSE TO EXTERNAL CONDITIONS OR USER OVERRIDE**




## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** assessed occupant satisfaction with EC windows in two buildings with curtain-wall construction—the 911 Federal Building in Portland, Oregon and the John E. Moss Federal Building in Sacramento, California.

## RESULTS

*How did EC windows perform in M&V?*

**63-92%**

**OCCUPANT PREFERENCE OVER EXISTING LOW-E[4]**

However, implementations that both satisfy occupants and meet competing performance requirements are challenging and take time.[5]

**CONTROL**

**BASELINE CONDITIONS AND OCCUPANT BEHAVIOR DETERMINE SAVINGS**

In Sacramento, most blinds remained lowered and darker tint levels predominated, resulting in a 62% increase in lighting energy. In Portland, 40% more blinds were left raised and lighter tint levels predominated, resulting in 36% lighting energy savings but a 2% HVAC increase.[6]

**NOT COST-EFFECTIVE FOR GENERAL OFFICE SPACE BASED ON ENERGY SAVINGS ALONE[7]**

Energy savings did not cover increased costs—in Portland, the incremental difference between installing spectrally selective low-e windows and EC windows was $37/ft$^2$.

## DEPLOYMENT

*Where does M&V recommend deploying EC windows?*

**FACILITIES WHERE OUTSIDE VIEWS ARE CRITICAL**

A previous GPG study recommended EC windows where glare control is required but blinds would interfere with mission, such as Land Ports of Entry.

EC windows also could enhance architectural features that provide a connection with the outdoors, such as skylights and atriums, though this has not been evaluated.

[1]*A Pilot Demonstration of Electrochromic and Thermochromic Windows in the Denver Federal Center*, Eleanor S. Lee (LBNL), March 2014, p.4 [2]Ibid, p.1 [3]*Electrochromic Window Demonstration at the Donna Land Port of Entry.* Luís L. Fernandes (LBNL), May 2015, p.37 [4] *Electrochromic Window Demonstration at the John E. Moss Federal Building. Sacramento*, Luís L. Fernandes (LBNL), August 2017, p.54 and *Electrochromic Window Demonstration at the 911 Federal Building, Portland Oregon*, Eleanor S. Lee (LBNL), August 2017, p.8 [5]Ibid, p.8 and p.136 [6]Ibid, p.3 and p.7 [7]Ibid, p.101 and p.7

GPG FINDINGS

# 034

APRIL 2018

# HIGH-PERFORMING COMMERCIAL ROOFTOP UNITS

## OPPORTUNITY

*RTUs condition how much floor space nationwide?*

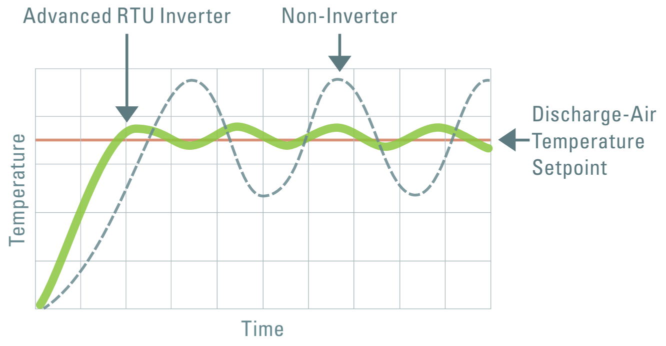
**>50%** **OF COMMERCIAL FLOOR SPACE IN THE U.S. IS CONDITIONED BY ROOFTOP UNITS (RTUS)[1]**

## TECHNOLOGY

*How do advanced RTUs work?*

**VARIABLE SPEED INVERTER COMPRESSOR MAINTAINS AIR TEMPERATURE SETPOINT**

VARIABLE SPEED SUPPLY FAN RESPONDS TO ZONE CONDITIONS




## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** (PNNL) assessed the first RTU to meet the Department of Energy's High Performance RTU Challenge. The RTU was provided by Daikin Applied and installed in a GSA warehouse in Fort Worth, Texas. PNNL also conducted a concurrent study of the advanced RTU at two Florida supermarkets.

## RESULTS

*How did the advanced RTU perform in M&V?*

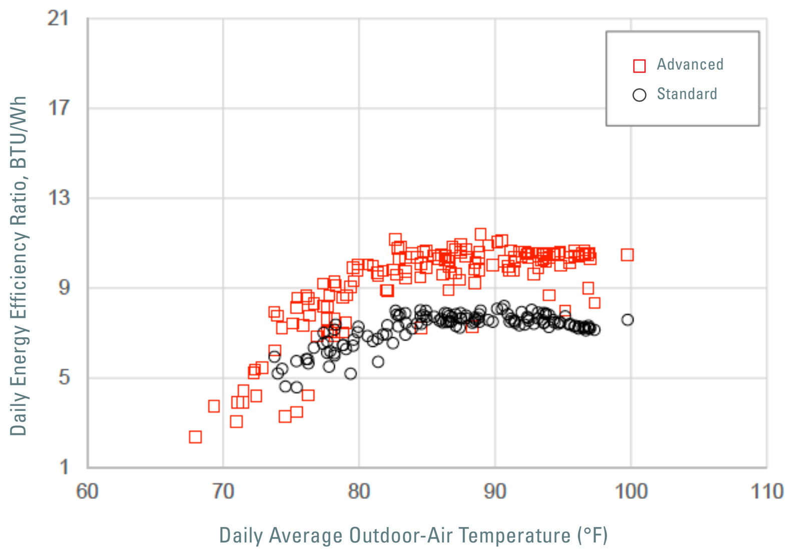
**26%**
**ENERGY SAVINGS**
Models predicted 40% savings compared to a standard RTU[2]

**COSTS**
**FOR INSTALLATION VARY**
Heavier unit and different footprint may require infrastructure reinforcement or duct changes[3]

**3.8 YR**
**PAYBACK**
demonstrated at two Florida supermarkets[4]

### Energy Efficiency Ratio as a Function of Outdoor Air Temperature

Advanced RTU exceeds baseline efficiency, particularly at higher outdoor air temperatures




## DEPLOYMENT

*Where does M&V recommend deploying advanced RTUs?*

**END-OF-LIFE REPLACEMENT**

Modeling indicates that savings will be greatest in hot, humid climates

[1]Field Evaluation of the Performance of the RTU Challenge Unit: Daikin Rebel, S. Katipaumla, W. Wang, H. Ngo, RM Underhill, Pacific Northwest National Laboratory, PNNL-26279, May 2017, p. 10 [2]Ibid, p. 25 [3]Ibid, p. 4 [4]Field Evaluation of the Performance of the RTU Challenge Unit: Daikin Rebel, S. Katipamula, W. Wang, H. Ngo, RM. Underhill, Pacific Northwest National Laboratory, PNNL-23672, March, 2015, p. 4

GPG FINDINGS 035

SEPTEMBER 2018

# SMALL CIRCULATOR PUMPS WITH AUTOMATED CONTROL

## OPPORTUNITY

*How much energy can high-performance circulator pumps save?*

**4.75 TWh**

**REPLACING 30 MILLION U.S. CIRCULATOR PUMPS**

WITH 50% HIGHER EFFICIENCY[1]

## TECHNOLOGY

*How do high-performance circulator pumps with automated control work?*

**< 2.5 HORSEPOWER PUMPS**

**VARIABLE SPEED**

**ELECTRONICALLY COMMUTED MOTORS**

ONBOARD CONTROL ALGORITHMS

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) measured performance of two common pump applications at two buildings within the Denver Federal Center—a domestic hot water (DHW) system and an air handler unit (AHU).

## RESULTS

*How did the small circulator pumps with automated control perform in M&V?*

**96%**

**ENERGY SAVINGS**

for DHW pump, 60% savings for AHU pump[2]

**MORE**

**OPERATIONAL VISIBILITY**

and reduced maintenance, no greasing of bearings or replacing pump seals [3]

**<6**

**YEAR PAYBACK**

@ 0.11/kWh GSA average utility rate and including annual maintenance savings[4]

## Payback and Savings Compared to Baseline Standard Pumps

Higher flow rates combined with smaller pump sizes offered the best return on investment

| | % Savings | Annual Energy Savings (kWh/yr) | Annual Energy Cost Savings @ 0.11 kWh ($) | Annual O&M Savings ($) | Incremental Cost ($) over market standard pump | Simple Payback | Savings-to-Investment Ratio (SIR) |
|---|---|---|---|---|---|---|---|
| **DHWP #1:** ¼ HP, 77 watts (duty point)<br>**Baseline:** ¼ HP, 280 watts (duty point) | 96% | 587 kW | $65 | $75 | $575 | 4.1 | 3.6 |
| **DHWP #2:** ¼ HP, 97 watts (duty point)<br>**Baseline:** ½ HP, 370 watts (duty point) | 96% | 1,039 kW | $114 | $75 | $575 | 3.0 | 4.9 |
| **AHU 19:** 0.36 HP, 186 watts (duty point)<br>**Baseline:** ½ HP, 223 watts (duty point)<br>4 hrs/day run-time | 26% | 45 kW | $5 | $75 | $500 | 6.3 | 2.4 |
| **AHU 19:** 0.36 HP, 186 watts (duty point)<br>**Baseline:** ½ HP, 330 watts (duty point)<br>20 hrs/day run-time | 60% | 688 kW | $76 | $75 | $500 | 3.3 | 4.5 |

## DEPLOYMENT

*Where does M&V recommend deploying small circulator pumps with automated control?*

**END-OF-LIFE REPLACEMENT**

**FOR CONSTANT-SPEED PUMPS**

Pumps used for DHW recirculation, small heating systems, small chilled water systems, solar hot water systems and small geothermal heat pump applications are all candidates for replacement.

[1]High-Performance Circulator Pump Demonstration, Jesse Dean, Anoop Honnekeri, Greg Barker, National Renewable Energy Laboratory (NREL), September 2018, p.4 [2]Ibid, p.30, 42 [3]Ibid, p.v [4]Ibid, p.v

SEPTEMBER 2018

# DUAL-ZONE INDOOR SHADES

## OPPORTUNITY

*How much energy can window technologies save in U.S. commercial buildings?*

**11%** **REDUCTION IN PRIMARY ENERGY USE**
WITH SOLAR CONTROL & DAYLIGHTING TECHNOLOGIES[1]

## TECHNOLOGY

*How do dual-zone indoor shades work?*

**UPPER ZONE FOR DAYLIGHT**
WITH AUTOMATICALLY- OR MANUALLY-CONTROLLED LOUVERS

**LOWER ZONE CONTROLS GLARE & PRESERVES VIEWS**

## M&V

*Where did Measurement and Verification occur?*

**LAWRENCE BERKELEY NATIONAL LABORATORY** measured performance of a dual-zone indoor shade provided by LouverShade at the Advanced Windows Testbed in Berkeley, CA against roller shades and venetian blinds. LBNL assessed facility manager and occupant satisfaction at the Ronald V. Dellums Federal Building in Oakland, CA, where the dual-zone shades replaced vertical blinds.

## RESULTS

*How did the dual-zone indoor shades perform in M&V?*

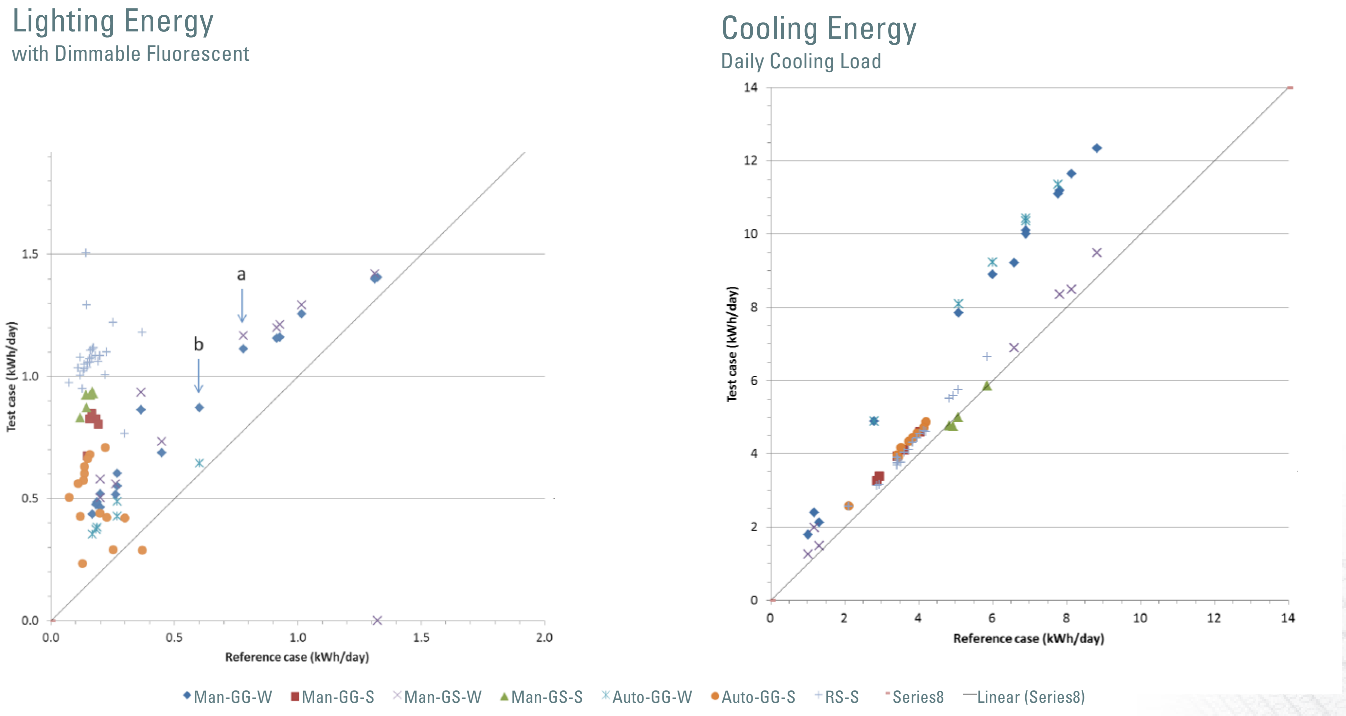
**DECREASE**
**IN ENERGY USE**
Compared to fabric roller shades (25% to 51% for lighting, -4% to 15% for cooling); *Increase* compared to venetian blinds (150% to 300% for lighting, 5% to 36% for cooling)[2]

**ROI**
**NEGATIVE**
Compared to both fabric roller shades and venetian blinds[3]

**80%**
**OCCUPANT PREFERENCE**
Over baseline vertical blinds[4]

### Measured Energy Use at the Advanced Windows Testbed

Compared to venetian blinds; points above diagonal line indicate that energy use is greater than venetian blinds




## DEPLOYMENT

*Where does M&V recommend deploying dual-zone indoor shades?*

**CONSIDER FOR REPLACEMENT**
**OF ROLLERSHADES**
Manual upper shades provided the best balance between financial performance and occupant response. Not broadly recommended to replace venetian blinds from a cost-savings standpoint.

[1]Dual-Zone Solar Control Indoor Shade, Eleanor S. Lee, Christoph Gehbauer, Anothai Thanachareonkit, Luís L. Fernandes, Taoning Wang, Lawrence Berkeley National Laboratory (LBNL), January 2018, p.7 [2]Ibid, p.30 [3]Ibid, p.47 [4]Ibid, p.44

GPG FINDINGS

# 037

NOVEMBER 2018

# ADVANCED LIGHTING CONTROLS AND LED

## OPPORTUNITY

*How can advanced lighting controls (ALC) support LED?*

LED'S DIGITAL NATURE PROVIDES MORE PRECISE DIMMING

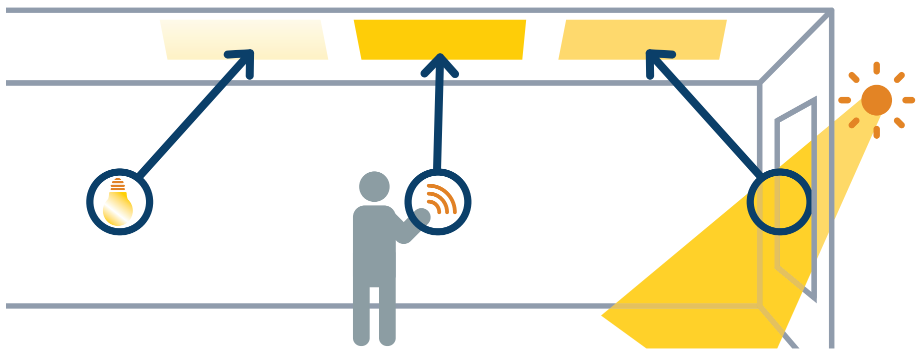
**MAKING ALC MORE EFFECTIVE**

## TECHNOLOGY

*What advanced lighting control strategies were assessed?*

**3 CONTROL STRATEGIES**

LIGHT-LEVEL TUNING, OCCUPANCY SENSING, DAYLIGHT HARVESTING



## M&V

*Where did Measurement and Verification occur?*

**PACIFIC NORTHWEST NATIONAL LABORATORY** (PNNL) assessed five different LED and advanced-control systems in open-plan offices at the Fort Worth Federal Center, Fort Worth, Texas

## RESULTS

*How did the advanced lighting controls perform in M&V?*

**43%**

**CONTROL SAVINGS**

from LED baseline, even with minimal daylight availability[1]

**TUNING**

**IS CRITICAL**

The ability to dim initial light levels significantly increased occupant satisfaction[2]

**ROI**

**VARIABLE**

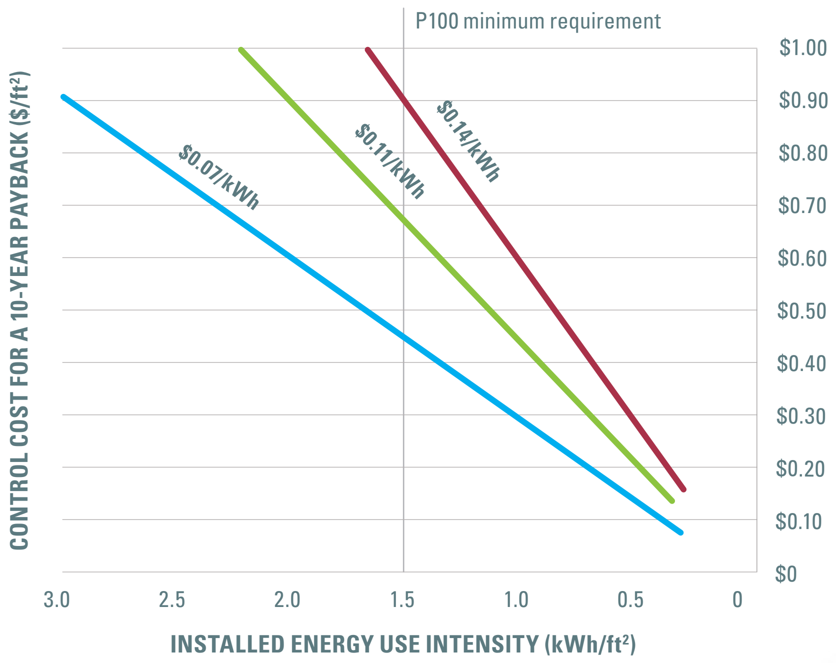
Can be cost-effective when the added cost of controls is <$70 per fixture @ GSA avg. utility $0.11/kW[3]

### ALC Costs Needed for a 10-Year Payback*

The more efficient the lighting, the more challenging for ALC to achieve positive ROI

ALC calculator at gsa.gov/gpg can help determine site-specific payback

*Assuming a 10-hour, 5-day work week and 43% ALC savings




## DEPLOYMENT

*Where does the study recommend deploying advanced lighting controls?*

**FACILITIES WITH HIGH UTILITY RATES**

Full-featured ALC will be most cost-effective for facilities with high utility rates and/or rebate opportunities and in open offices where occupants are engaged in a variety of tasks.

If ALC is not cost-effective, choose LED systems with dedicated 0-10V drivers that provide dimming. Tuning can be key to occupant satisfaction.

[1]Evaluation of Advanced Lighting Control Systems in a Working Office Environment, M. Myer, Pacific Northwest National Laboratory, (PNNL-27619), September 2018, p.3 [2]Ibid, p.26 [3]Ibid, p.35

GSA

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DECEMBER 2018

# ELECTROCHEMICAL WATER TREATMENT

## OPPORTUNITY

*How much water do cooling towers use?*

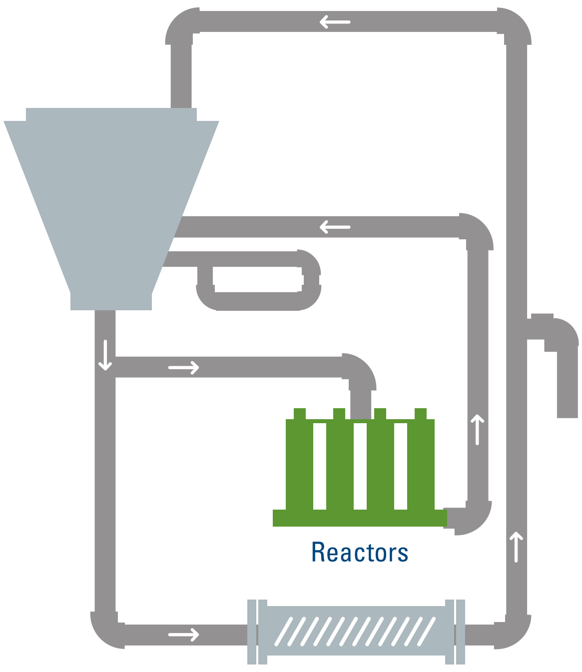
**28% OF WATER IN COMMERCIAL BUILDINGS** IS USED BY COOLING TOWERS OR OTHER HEATING AND COOLING SYSTEMS[1]

## TECHNOLOGY

*How does electrochemical water treatment work?*

**ELECTROLYSIS SEQUESTERS SCALE IN REACTOR TUBES**

AND CREATES CHLORINE, A NATURAL BIOCIDE




## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed an alternative water treatment (AWT) system provided by Dynamic Water Technology for two 150-ton cooling towers in Savannah, Georgia.

## RESULTS

*How did electrochemical water treatment perform in M&V?*

**32% WATER SAVINGS**
99.8% reduction in blowdown[2]

**50% MAINTENANCE REDUCTION**
Small cost increase in annual O&M contract[3]

**100% CHEMICAL SAVINGS**
Technology generates chlorine; reduced slime[4]

**2.5 YEAR PAYBACK**
@ GSA avg. water/sewer $16.76/kgal[5]

### Electrochemical Water Treatment Return-On-Investment

Rebates for AWT systems are available through some local water utilities

| | Testbed (Before) | Testbed (After)+ | GSA Normalized (After)* |
|---|---|---|---|
| Equipment ($) | N/A | $30,340 | $30,340 |
| Installation ($) | N/A | $29,029 | $15,000 |
| Maintenance (yr) | $5,280 | $6,000 | $6,000 |
| Maintenance Savings (yr) | N/A | -$720 | -$720 |
| Water Consumption (Gallons/yr) | 3,588,156 | 2,454,299 | 2,454,299 |
| Water Savings (Gallons/yr) | N/A | 1,133,857 | 1,133,857 |
| Water Savings ($/yr) | N/A | $7,529 | $19,003 |
| Simple Payback (yrs) | | 8.7 | 2.5 |
| Savings to Investment Ratio | | 1.7 | 6.0 |

+ Savannah testbed water/sewer $6.64/kgal   * GSA average water/sewer $16.76/kgal, normalized installation cost

## DEPLOYMENT

*Where does the study recommend deploying electrochemical water treatment?*

**CONSIDER FOR ALL COOLING TOWERS**

Most cost-effective in areas with high water costs or where water is excessively hard, has high pH values and/or large amounts of total dissolved solids

[1]Electrolysis Water Treatment for Cooling Towers, Gregg Tomberlin, Jesse Dean, Jimmy Salasovich (NREL), December 2018, p.9
[2]Ibid, p.21 [3]Ibid, p.23 [4]Ibid, p.24 [5]Ibid, p.26

JANUARY 2019

# ADVANCED OXIDATION PROCESS FOR COOLING-TOWER WATER

## OPPORTUNITY

*How much water do cooling towers routinely blow down?*

**UP TO 50% COOLING WATER IS FLUSHED** TO MINIMIZE SCALE BUILD-UP[1]

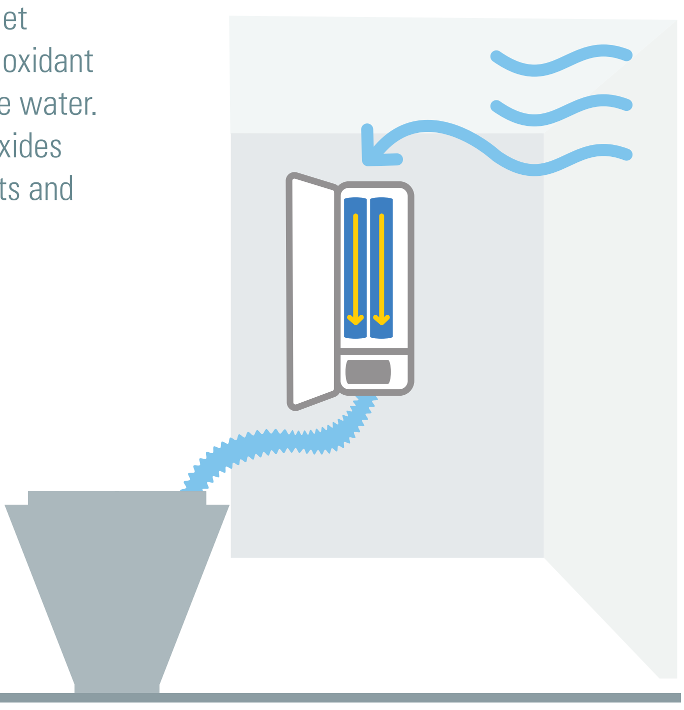
## TECHNOLOGY

*How does the advanced oxidation process (AOP) for cooling towers work?*

### PHOTOCHEMICAL TREATMENT

OXIDIZES MINERALS AND CONTAMINANTS

Air drawn into the ultraviolet reactor generates a mixed oxidant gas that is diffused into the water. Hydroxyl radicals and peroxides form to attack contaminants and oxidize minerals.



## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed an advanced oxidation process system provided by Silver Bullet Water Treatment Company in two 250-ton cooling towers at the Denver Federal Center (DFC)

## RESULTS

*How did the advanced oxidation process perform in M&V?*

**26% WATER SAVINGS**
Estimated savings from 23% to 30%[2]

**50% MAINTENANCE REDUCTION**
Reduced scaling might also save energy, though this was not assessed[3]

**MET GSA WATER STANDARDS**
No additional chemicals were needed[4]

**2 YEAR PAYBACK**
@ GSA avg. water/sewer $16.76/kgal[5]

### Advanced Oxidation Process Return-On-Investment

@ GSA average water/sewer cost of $16.76/kgal

| | Baseline (Before) | AOP System (After) |
|---|---|---|
| Installed Equipment (two 250-ton cooling towers)* | N/A | $22,487 |
| Annual Maintenance | $5,855 | $3,333 |
| Annual Water Consumption (gal/yr) | 2,003,273 gal | 1,475,482 gal |
| Annual Energy Costs (5,250 kWh/yr @$0.11/kWh) | $0 | $578 |
| Annual Water Costs (@$16.76 kgal/yr) | $14,303 | $5,457 |
| **Payback (yrs)** | | **2.1** |
| **Savings-to-Investment Ratio** | | **7.2** |

*Normalized installation cost of one unit

## DEPLOYMENT

*Where does the study recommend deploying the AOP system?*

### CONSIDER FOR ALL COOLING TOWERS

Anticipate changes needed to O&M contracts to transition from traditional chemical treatment to alternative water treatment systems

[1]Demonstration and Evaluation of an Advanced Oxidation Technology for Cooling Tower Water Treatment, Jesse Dean, Dylan Cutler, Gregg Tomberlin, James Elsworth (NREL), December 2018, p.1 [2]Ibid, p.17 [3]Ibid, p.20,21 [4]Ibid, p.17 [5]Ibid, p.20

GPG FINDINGS

# 040

FEBRUARY 2019

# ALTERNATIVE WATER TREATMENTS FOR COOLING TOWERS

## OPPORTUNITY

*Why is GSA interested in alternative water treatments?*

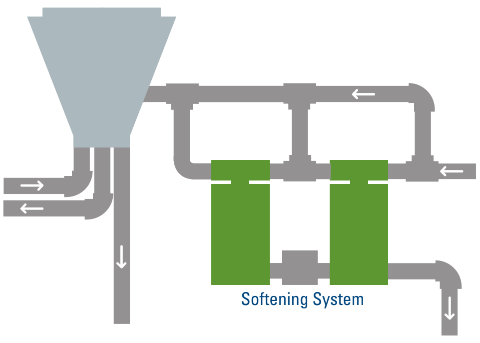
**41%** **INCREASE IN GSA WATER RATES 2014-2017**[1]

## TECHNOLOGY

*How do these alternative water treatments work?*

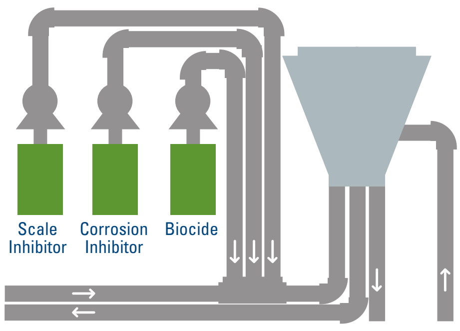
### SALT-BASED ION EXCHANGE

REMOVES HARDNESS WITHOUT ADDITIONAL CHEMICALS




### CHEMICAL SCALE INHIBITION

PROPRIETARY CHEMICALS INHIBIT SCALING AND CORROSION




## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed three alternative water treatment (AWT) systems at the Denver Federal Center. Two out of the three systems maintained adequate water quality.

## RESULTS

*How did these alternative water treatments perform in M&V?*

**23%** **WATER SAVINGS**
94%-99% reduction in blowdown[2]

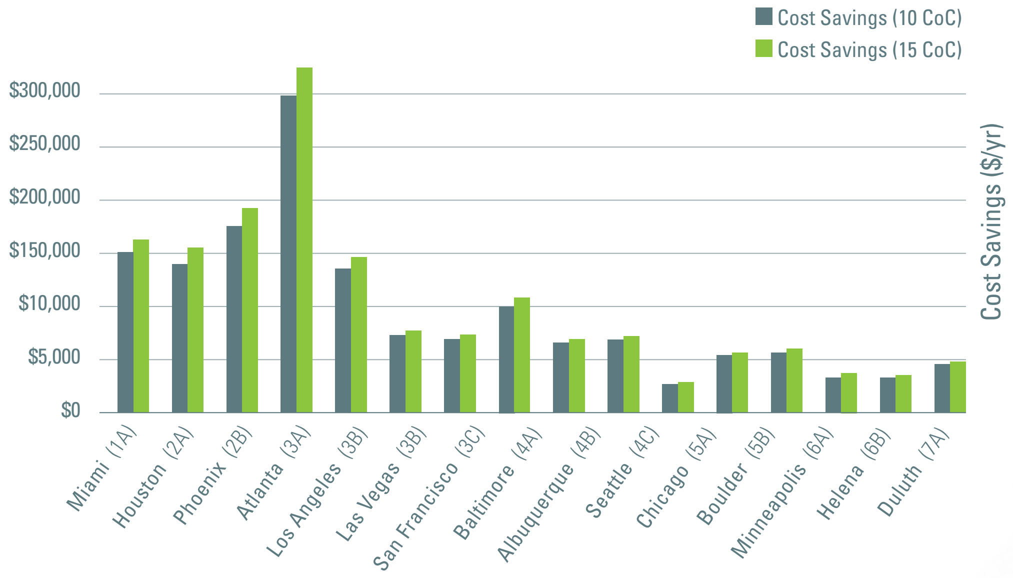
**O&M** **VARIABLE**
Chemical scale inhibition increased O&M costs, salt-based reduced them[3]

**IMPROVED CHILLER OPERATIONS**
Cleaner condenser tubes, increased heat exchanger effectiveness[4]

**<3 YEAR PAYBACK**
@ GSA average water/sewer cost of $16.76/kgal[5]

### Modeled Cost Savings per Cycles of Concentration (CoC)

Most water savings are achieved by a CoC of 10; both systems achieved CoCs greater than 12




## DEPLOYMENT

*Where does the study recommend deploying alternative water treatments?*

### CONSIDER FOR ALL COOLING TOWERS

Both salt-based and chemical-scale inhibition systems can be retrofitted to any cooling tower.

[1]Electrochemical Water Treatment for Cooling Towers, Gregg Tomberlin, Jesse Dean, Michael Deru (NREL), February 2019, p.26
[2]Alternative Water Treatment Technologies for Cooling Tower Applications, Dylan Cutler, Jennifer Daw, P.E., Dan Howett, P.E. Jesse Dean (NREL), February 2019, p.6 [2]Ibid, p.31, 33 [3]Ibid, p.35 [4]Ibid, p.6 [5]Ibid, p.6

GSA

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GPG FINDINGS 041

MAY 2019

# SUBMETERS AND ANALYTICS: FULL PANEL

## OPPORTUNITY

*Why is GSA interested in circuit-level submetering and analytics?*

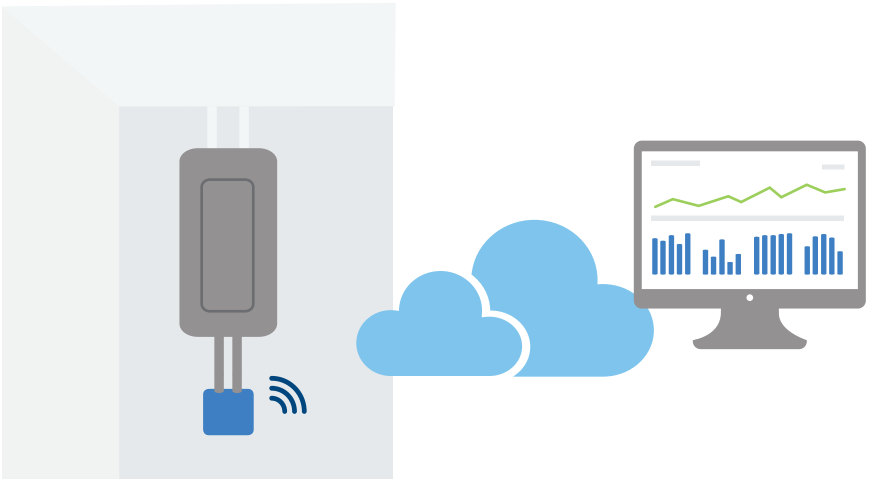
**MONITOR AND ANALYZE INDIVIDUAL CIRCUITS FOR GRANULAR ELECTRIC CONSUMPTION**

## TECHNOLOGY

*How does the full-panel submetering and analytics system work?*

**METER & DATA STORAGE WITH CLOUD-BASED ANALYTICS**

Monitors up to 42 circuits; voltage taps power the system



## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed the full-panel submetering and analytics system at the Salt Lake City Courthouse. Technology was provided by Enertiv.

## RESULTS

*How did full-panel submetering and analytics perform in M&V?*

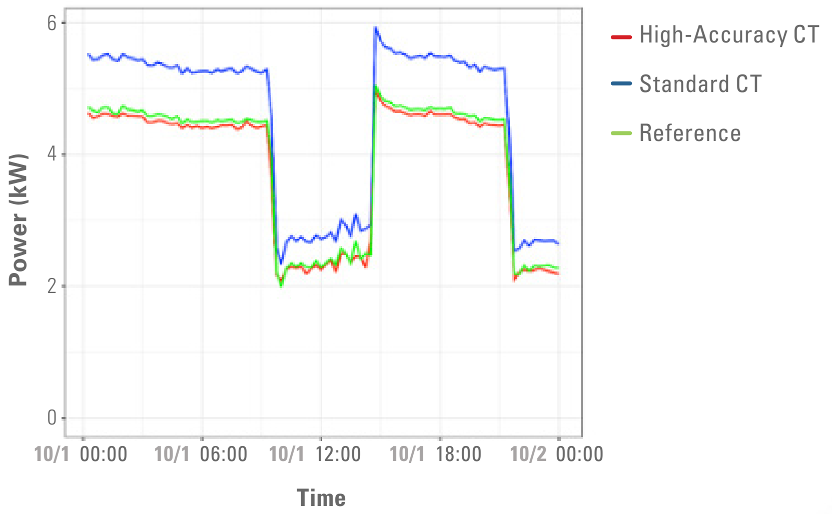
**<3%**
**ERROR IN MEASUREMENT**
using high-accuracy current transformers (CTs) which are critical for low power circuits[1]

**10%**
**HVAC LOAD SAVINGS**
by utilizing submeter data that identified lead/lag programming issue[2]

**1 YR PAYBACK**
based on accurate costs for overtime tenant billing. Metered energy use was double calculated estimate[3]

### High-Accuracy CTs Tracked with Revenue-Grade Reference Submeter

Standard-accuracy CTs did not meet requirements for tenant billing




## DEPLOYMENT

*Where does the study recommend deploying full-panel submetering and analytics?*

**ACCURATE TENANT BILLING**

Most value when monitoring overtime utilities or devices that have high power consumption. Pilot project recommended to determine best practices, including changes to GSA billing practices.

[1]Case Study: Laboratory and Field Evaluation of Circuit-Level Submetering with an Integrated Metering System, Dylan Cutler, Willy Bernal Heredia, Jesse Dean (NREL), May 2019, p.27 [2]Ibid, p.30 [3]Ibid, p.37

GPG FINDINGS

# 042

JUNE 2019

# SUBMETERS AND ANALYTICS: WIRELESS CURRENT TRANSFORMERS

## OPPORTUNITY

*Why is GSA interested in submetering and analytics?*

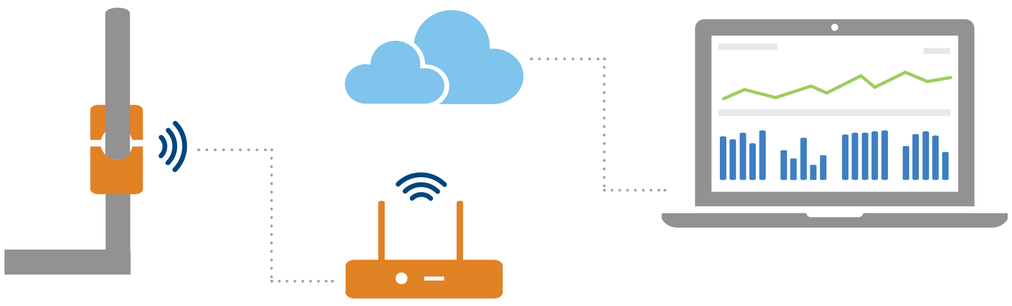
- TENANT OR EQUIPMENT-LEVEL BILLING
- FAULT DETECTION & DIAGNOSTICS (FDD)
- ENERGY CONSERVATION MEASURES (ECMS)

## TECHNOLOGY

*What are wireless current-transformers (CT)?*

### CLIP-ON SENSORS POWERED BY CURRENT IN ELECTRICAL WIRE

No meter, wiring or conduit required; data sent to the cloud



## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed wireless CTs at the Cesar Chavez Memorial Building in Denver, Colorado. Technology was provided by Centrica.

## RESULTS

*How did wireless CTs perform in M&V?*

**FDD ACTIONABLE**

Insights included short-cycling, on/off issues, and seasonal trends[1]

**1 DAY INSTALLATION**

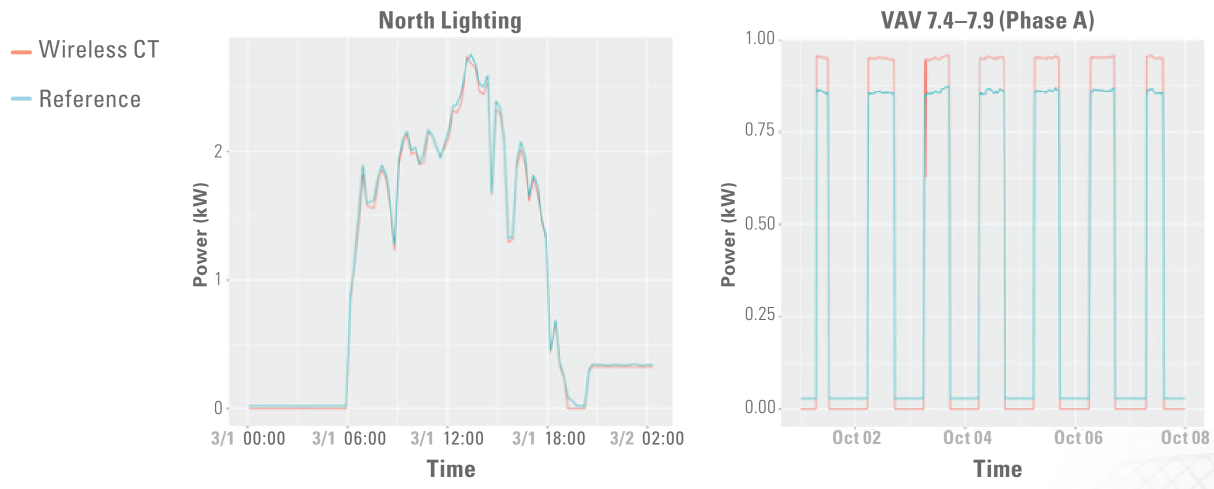
for 144 individual circuits in 13 panels and 4 HVAC equipment disconnects. Configuration software streamlined the process with real-time feedback[2]

**7% AVG. ERROR IN MEASUREMENT**

up to 52% measured error with VAV & loads with heavy cycling; not accurate enough for tenant billing[3]

### Accurately Tracks Load Profile Trends

Precisely tracks on/off state of equipment, supporting FDD




## DEPLOYMENT

*Where does the study recommend deploying wireless CTs?*

### FAULT DETECTION & DIAGNOSTICS

Wireless CTs can monitor systems not typically monitored by a building automation system and can be integrated into GSA's smart building platform, GSALink. Pilot project recommended to determine best practices, cost-benefit analysis and site selection.

[1]Case Study: Laboratory and Field Evaluation of Circuit-level Electrical Submetering with Wireless Current Transformers, Willy Bernal Heredia, Dylan Cutler, Jesse Dean (NREL), June 2019, p.32 [2]Ibid, p.31 [3]Ibid, p.28

NOVEMBER 2019

# SOFTWARE-CONTROLLED SWITCHED RELUCTANCE MOTOR

## OPPORTUNITY

*Why is GSA interested in smart motors?*

**38%** OF ELECTRICITY IS USED BY MOTORS IN U.S. COMMERCIAL BUILDINGS[1]

**56%** OF MOTORS ARE < 5 HP[2]

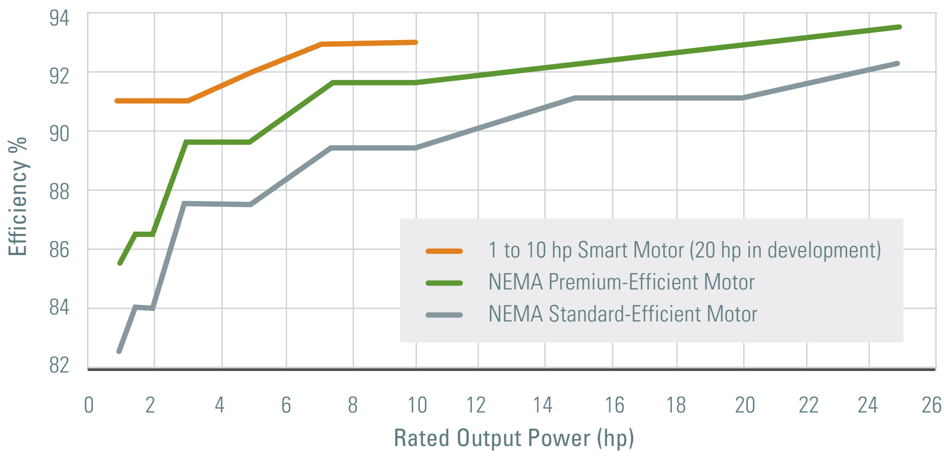
## TECHNOLOGY

*What are smart motors?*

### SOFTWARE-CONTROLLED SWITCHED RELUCTANCE MOTOR WITH VARIABLE-FREQUENCY DRIVE (VFD)

**REAL-TIME CLOUD-BASED MONITORING AND CONTROL**

**Smaller motors offer greater relative savings**




## M&V

*Where did Measurement and Verification occur?*

**OAK RIDGE NATIONAL LABORATORY** (ORNL) assessed a 10 hp smart motor on a chilled water pump application at the Land Port of Entry in San Ysidro, California. A concurrent National Renewable Energy Laboratory (NREL) assessment of a 1.5 hp motor took place on condenser fans in a refrigeration system at a Walmart in Lakeside, Colorado. Technology was provided by Software Motor Company.

## RESULTS

*How did the 10 hp smart motor perform in M&V?*

**MORE**
**EFFICIENT UNDER ALL CIRCUMSTANCES**
4% avg. savings compared to a premium-efficient motor & VFD.[3] *33% for 1.5 hp motor compared to a standard-efficient motor & VFD (NREL assessment)*[4]

**O&M**
**INSTALLATION COMPARABLE**
Reduced maintenance. Drop-in motor replacement[5]

**REMOTE**
**MONITORING & CONTROL**
Possible but not tested. *NREL assessment showed successful fault-detection and control*[6]

### Immediate Payback When Replaced at End-of-Life

44% less expensive than a code-compliant premium-efficiency motor and VFD

| | Premium Motor + VFD | Smart Motor (Retrofit) | Smart Motor (End-of-Life) |
|---|---|---|---|
| 10 hp motor cost ($)+ | $4,375 | $2,430 | $1,945 less expensive |
| Installation ($)++ | $948 | $948 | $0, no change |
| Technology electricity use (kWh/yr) | 31,700 kWh | 30,400 kWh | 1,300 kWh annual energy savings |
| Technology electricity @ GSA avg. $0.11/kWh ($/yr) | $3,516 | $3,371 | $145 annual cost savings @ $0.11/kWh |
| Simple payback (yrs) | | 23 | Immediate |

+ Premium motor ($1,756) and VFD ($2,619) cost provided by San Ysidro LPOE. Smart motor cost provided by manufacturer; does not include volume discounts. EISA 2007 mandates 1-to-200 hp premium-efficiency motors. GSA's facilities standards guide, the P100, requires a VFD on all motors larger than 5 hp.
++ Labor cost provided by San Ysidro LPOE: 12 hours @ $79/hr. Pump application requires laser alignment to align pump and motor.

## DEPLOYMENT

*When does the study recommend deploying smart motors?*

### END-OF-LIFE REPLACEMENT

Also consider retrofits for: fixed-speed motors; motors < 5 hp; and applications with lower installation costs, such as motors that control fans

[1] *Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems*, International Energy Agency, Paul Waide and Conrad U. Brunner, 2011, p.11 [2] *Premium Efficiency Motor Selection and Application Guide*, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, February 2014, p.1-5 [3] *Laboratory Evaluation and Field Demonstration of High Rotor Switched Reluctance Motor Technology*, Brian Fricke, Mahabir Bhandari (ORNL), October 2019, p.32 [4] *Evaluation of High Rotor Pole Switched Reluctance Motors to Control Condenser Fans in a Commercial Refrigeration System*, Grant Wheeler, Michael Deru (NREL), June 2019, p.18 [5] ORNL Report, October 2019, p.37 [6] NREL Report, June 2019, p.19

GPG FINDINGS

# 044

JANUARY 2020

# ALTERNATIVE WATER TREATMENT FOR COOLING TOWERS

## OPPORTUNITY

*How much water do cooling towers routinely flush from the system?*

**UP TO 50% COOLING WATER IS "BLOWDOWN"** TO MINIMIZE SCALE BUILD-UP[1]

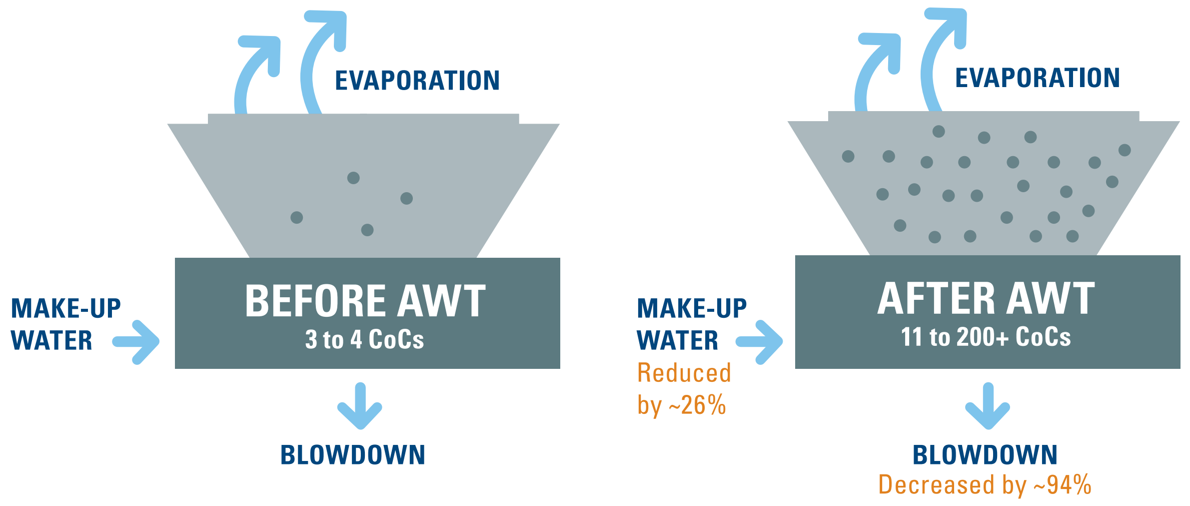
## TECHNOLOGY

*How do Alternative Water Treatment (AWT) systems work?*

**INCREASE CoC (CYCLES OF CONCENTRATION)**

**WHILE CONTROLLING SCALE & CORROSION**

AWT systems hold minerals in suspension at increased CoCs




## M&V

*Where did Measurement and Verification (M&V) occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) has assessed four AWT systems, three at the Denver Federal Center and one in Savannah, Georgia. Two more assessments are underway with results due by 2021.

## RESULTS

*How did the four AWT systems perform in M&V?*

**26% AVG. WATER SAVINGS**
Savings ranged from 23% to 32%; blowdown reduced 94% to 99%[2]

**50% REDUCTION IN TOWER CLEANING**
due to less scale and corrosion[3]

**MET GSA WATER STANDARDS**
including controlling for legionella[4]

**2-3 YEAR PAYBACK**
@ 2017 GSA avg. water/ sewer $16.76/ kgal[5]

### Positive Return on Investment for all Systems

@ 2017 GSA average water/sewer cost of $16.76/kgal

| | Electrochemical | Advanced Oxidation | Salt-Based | Chemical-Scale |
|---|---|---|---|---|
| Cooling Tower Size (tons) | 300 (2 x 150) | 500 (2 x 250) | 1,500 (3 x 500) | 1,200 (2 x 600) |
| Installed Cost | $45,340 | $23,425 | $29,600 | $32,511 |
| Installed Cost Per Ton | $151 | $47 | $20 | $27 |
| Annual Maintenance Change | +$720 | -$2,522 | -$6,445 | +$1,883 |
| Annual Electricity Increase (@$0.11/kWh) | $3,049 | $582 | | |
| Water Savings Per Ton-Hour of Cooling | 0.64 | not measured | 0.58 | 0.42 |
| Annual Water Savings (@$16.76 kgal/yr) | $19,003 | $8,846 | $6,724 | $13,818 |
| **Payback (yrs)** | **3.0** | **2.2** | **2.2** | **2.7** |
| **Savings-to-Investment Ratio** | **5.0** | **6.9** | **6.7** | **5.5** |

## DEPLOYMENT

*Where do the assessments recommend deploying AWT systems?*

**ALL COOLING TOWERS**

Anticipate changes needed to O&M contracts to transition from traditional chemical treatment to alternative water treatment systems.

[1]Demonstration and Evaluation of an Advanced Oxidation Technology for Cooling Tower Water Treatment, Jesse Dean, Dylan Cutler, Gregg Tomberlin, James Elsworth (NREL), December 2018, p.1 [2]GSA Guidance—Alternative Water Treatment Systems for Cooling Towers, Jesse Dean (NREL), Gregg Tomberlin (NREL), Andrea Silvestri (Tenfold Information Design), January 2020, p.6 [3]Ibid, p.9 [4]Ibid, p.7 [5]Ibid, p.11

OCTOBER 2020

# AWT: CONTINUOUS MONITORING AND PARTIAL WATER SOFTENING

## OPPORTUNITY

*Why is GSA interested in alternative water treatments (AWT)?*

**UP TO 50% COOLING WATER IS FLUSHED** TO MINIMIZE SCALE BUILD-UP[1]

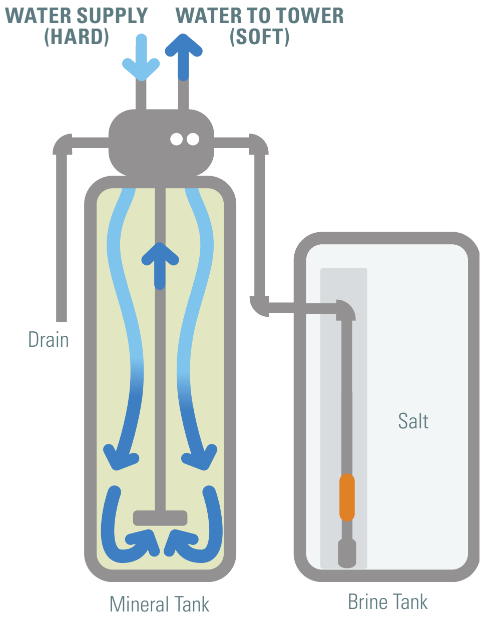
## TECHNOLOGY

*How does the continuous monitoring and partial water softening system work?*

### PARTIAL SOFTENING INCREASES BLOWDOWN SETPOINT

SUPPLEMENTAL TREATMENT SYSTEM DETERMINES OPTIMAL BLOWDOWN TO SATISFY WATER CHEMISTRY TARGETS; SIDESTREAM FILTRATION FILTERS DEBRIS

Real-time monitoring sends system alarms via built-in display or integrated with building management system




## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed a continuous monitoring and partial-water softening system provided by Aqualogix in three cooling towers at the Lloyd D. George Courthouse in Las Vegas, Nevada

## RESULTS

*How did the monitoring and partial-softening system perform in M&V?*

**15% WATER SAVINGS**
52% reduction in blowdown[2]

**MET GSA WATER STANDARDS**
Monitors performance and sends alarms[3]

**O&M UNCHANGED**
Works alongside traditional chemical treatment[4]

**3 YEAR PAYBACK**
@ GSA avg. water/sewer $16.76/kgal[5]

### Monitoring and Partial-Softening Return-On-Investment

@ 3-million ton target load and GSA average water/sewer cost of $16.76/kgal

| | Monitoring & Partial Softening |
|---|---|
| Installed Equipment (200-1000 ton load)* | $38,371 |
| Annual Maintenance* | $783 |
| Annual Energy Increase (7,735 kWh/yr @$0.11/kWh) | $851 |
| Water Savings (938,273 kgal @$16.76 kgal/yr) | $16,480 |
| **GSA Average Payback (yrs)*** ** | **2.6** |
| **GSA Average Savings-to-Investment Ratio** | **5.8** |

*GSA discounted pricing **$250 for annual calibration, $533 for salt ***Payback assumes target load of 3-million ton hours and GSA utility rates. Payback at the testbed was 7.5 years based on the measured 1.6 million ton hour load and utility rate of $12.59 kgal

## DEPLOYMENT

*Where does the assessment recommend deploying this AWT system?*

### CONSIDER FOR ALL COOLING TOWERS

Continues standard and familiar water treatment practices and may offer an easier and more failsafe deployment opportunity for GSA facilities

[1]Continuous Monitoring and Partial Water Softening for Cooling Tower Water Treatment, Gregg Tomberlin, Jesse Dean, Michael Deru (NREL), October 2020, p.9 [2]Ibid, p.24 [3]Ibid, p.28 [4]Ibid, p.26 [5]Ibid, p.31

GPG FINDINGS

# 046

JANUARY 2021

# SUBMETERS AND ANALYTICS: SINGLE-CIRCUIT METER

## OPPORTUNITY

*Why is GSA interested in submetering and analytics?*

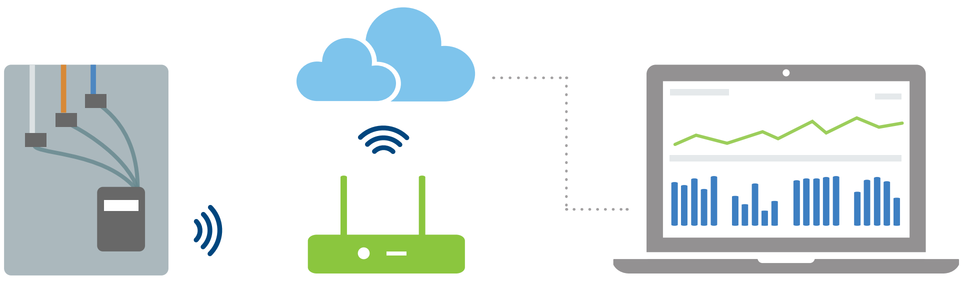
- TENANT OR EQUIPMENT-LEVEL BILLING
- FAULT DETECTION & DIAGNOSTICS (FDD)
- IDENTIFY ENERGY CONSERVATION MEASURES (ECMS)

## TECHNOLOGY

*What are single-circuit meters?*

### MONITOR SINGLE OR 3-PHASE CIRCUITS INCLUDING PANEL MAINS

Combines a meter, a wireless communication gateway that collects data from multiple meters, non-proprietary current transformers and cloud-based analytics



## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed single-circuit meters at the Cesar Chavez Memorial Building in Denver, Colorado. Technology was provided by Meazon.

## RESULTS

*How did single-circuit meters perform in M&V?*

**<2% ERROR COMPARED TO REFERENCE**

Captured load profile trends accurately, even for high-variability loads[1]

**1 DAY INSTALLATION**

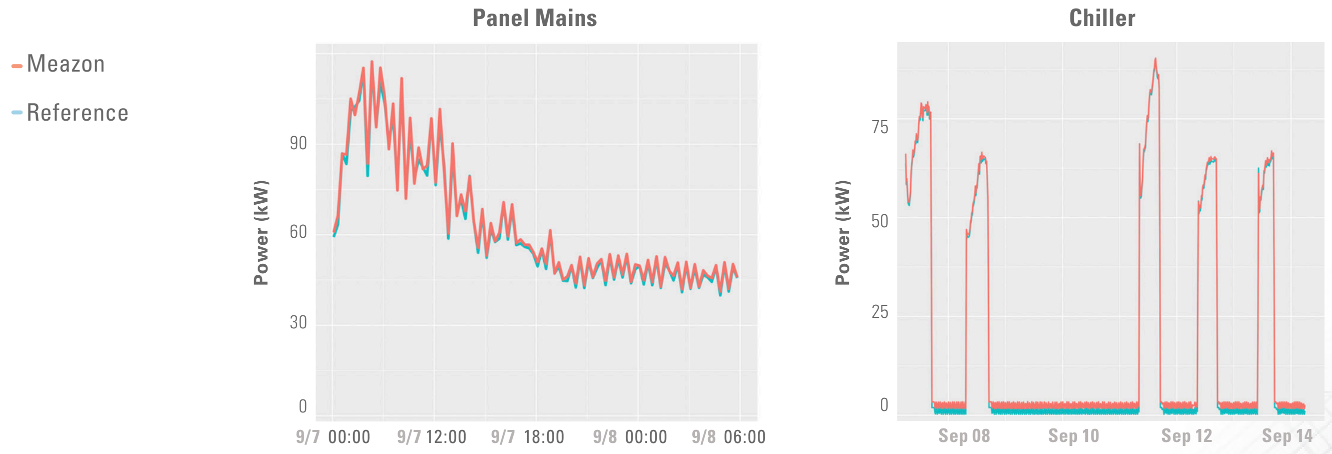
for 6 measured loads; $470 equipment and $431 installation per load; equipment bulk purchase estimate $132/load.[2]

**FDD/ECM**

Provides basic fault-detection and energy conservation measures for facilities without a BAS; can also be integrated into GSA's smart building platform, GSALink.[3]

### Accurately Tracks Energy Consumption

<2% measurement error, except when chillers were online but idling[4]




## DEPLOYMENT

*Where does the study recommend deploying single-circuit meters?*

### TENANT BILLING

Most value for monitoring devices with high power consumption.

Low-cost submetering can also provide FDD for facilities without GSALink and support ECM identification and M&V.

[1]Case Study: Field Evaluation of a Low Cost Circuit-Level Electrical Submetering System, Willy Bernal Heredia, Dylan Cutler, Jesse Dean (NREL), January 2021, p.23 [2]Ibid, p.25 [3]Ibid, p.29 [4]The decrease in measurement accuracy for low-power loads is consistent with previous GPG submetering evaluations. New meter design & high accuracy CTs may mitigate measurement errors for low-power loads.

GPG FINDINGS 047

MAY 2021

# PV RESILIENCE: ADDRESSING WEATHER VULNERABILITIES

## GSA INVESTMENT IN PV

*How many solar installations does GSA have?*

**154** GSA FACILITIES HAVE PV ARRAYS

**27MW** TOTAL SYSTEM CAPACITY

### PV IS RELIABLE

IN AN ANALYSIS OF 100,000 PV SYSTEMS, 80% TO 90% PERFORMED WITHIN 10% OF PREDICTED PRODUCTION OR BETTER[1]

## IMPACT OF 2017 HURRICANE SEASON

*What was the major vulnerability found across PV arrays in Region 2?*

**BERKELEY LAB AND NATIONAL RENEWABLE ENERGY LABORATORY** assessed the impact of the 2017 hurricane season on 5 PV arrays in the Caribbean

### INADEQUATE FASTENERS

**FOUND ACROSS ALL SITES**

SMALL UP-FRONT INVESTMENT IN LOCKING HARDWARE, CLAMPS, AND THROUGH-BOLTING CAN HELP PROTECT PV ARRAYS[2]

## DEVELOPING GUIDANCE

*Addressing weather vulnerabilites*

**BERKELEY LAB** worked with the Federal Energy Management Program (FEMP) to identify additional weather vulnerability risks

**RISK ASSESSMENT**
FOR SAFETY, PERFORMANCE AND FINANCIAL[3]

**27 CORRECTIVE ACTIONS**
MANY ARE LOW COST[4]

**CONSULT QUALIFIED ENGINEERS**
TO INTEGRATE BEST PRACTICES[5]

## KEY VULNERABILTIES AND POTENTIAL SOLUTIONS

*What are the key vulnerabilities that lab researchers identified?*

### STRUCTURAL VULNERABILITIES

**Top down clamps loosening or bending**
To correct: Use through-bolting or top-down clamps with improved features[6]

**Inadequate structural attachments to building in roof arrays**
To correct: Add mechanical attachments to improve structural integrity[7]

### ELECTRICAL VULNERABILITIES

**Improper wire management**
To correct: Protect wires from weather and support every 12 inches with clamps, clips or ties[8]

**Inadequate electrical enclosures**
To correct: Use proper NEMA-rated enclosures for the site's environmental conditions[9]

### SITE VULNERABILITIES

**Unobstructed wind forces**
To correct: Use a wind calming fence to reduce wind forces on the PV system[10]

**Loose debris and equipment**
To correct: Secure or remove loose equipment and debris from the area around the PV system[11]

*Structural vulnerabilities exhibit the greatest safety, performance and financial risks. Wind is the most damaging weather factor and also the most complex to understand and plan for.*

[1]Jordan, DC, Marion, B, Deline, C, Barnes, T, Bolinger, M. PV field reliability status—Analysis of 100 000 solar systems. *Prog Photovolt Res Appl.* 2020; 28: 739– 754 [2]Solar Array Inspection, Failure Analysis, Specifications and Repair Scopes of Work, Caribbean Region. Gerald Robinson (LBNL), Andy Walker and Ran Fu (NREL) April 2018, p.9 [3]Federal Solar Photovoltaic Arrays, Gerald Robinson (LBNL) December 2020, p.6 [4]Ibid, p.14 [5]Ibid, p.8 [6]Ibid, p.19 [7]Ibid, p.32 [8]Ibid, p.39 [9]Ibid, p.50 [10]Ibid, p.55 [11]Ibid, p.58

GPG FINDINGS

# 048

NOVEMBER 2021

# LIGHTWEIGHT QUAD-PANE WINDOWS

## OPPORTUNITY

*Windows are responsible for how much energy use?*

**34%** **OF COMMERCIAL BUILDING HVAC ENERGY IS LOST THROUGH WINDOWS[1]**

An improved building envelope minimizes HVAC loads and contributes to Net-Zero goals

## TECHNOLOGY

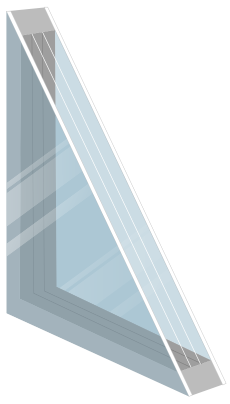
*How are Lightweight Quad-Pane Windows made?*

**4 PANES IN INSULATED FIBERGLASS FRAME WITH**

**WARM-EDGE SPACERS & KRYPTON GAS**

**R-8 RATED FULL-FRAME INSULATING VALUE**

2 configurations: 2 outer panes of low-e glass containing either 2 panes of thin glass or 2 layers of suspended film



## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** (NREL) assessed quad-pane windows provided by Alpen High Performance Products at the Denver Federal Center. One option used thin glass and one used suspended film.

## RESULTS

*How did Lightweight Quad-Pane Windows perform in M&V?*

**24%**

**AVERAGE HVAC SAVINGS***

SUSPENDED-FILM CONFIGURATION SAVED 1% MORE ENERGY THAN THIN GLASS OPTION[2]

*Compared to high-performance double-pane window

**HVAC**

**CAPITAL SAVINGS**

REDUCES REQUIRED SIZE OF HVAC EQUIPMENT; MODELING ESTIMATES $120K IN EQUIPMENT SAVINGS FOR A 498K SF BUILDING[3]

**SAME**

**INSTALLATION**

IDENTICAL THICKNESS, COMPARABLE WEIGHT, ~10% MORE EXPENSIVE THAN HIGH-PERFORMING DOUBLE-PANE[4]

## Positive Return on Investment Across Climate Zones

New construction payback < 3 years at average GSA utility rates, $0.11/kWh and $7.43/MMBtu[5]

| Location | | Savings from High-Performance Double-Pane to Quad-Pane Thin Glass* | | | | | |
|---|---|---|---|---|---|---|---|
| CLIMATE ZONE | CITY | HEATING kBtu/ft2/yr | COOLING kBtu/ft2/yr | FAN kBtu/ft2/yr | TOTAL % | PAYBACK* YRS | SIR positive ROI if >1 |
| 1A | Miami, FL | 0.64 | 2.29 | 1.61 | 19% | 1.7 | 12.1 |
| 2A | Dallas, TX | 1.09 | 2.36 | 1.59 | 20% | 1.5 | 12.9 |
| 2B | Phoenix, AZ | 1.13 | 2.16 | 2.00 | 25% | 1.5 | 13.3 |
| 3A | Atlanta, GA | 1.97 | 2.31 | 1.65 | 24% | 1.4 | 14 |
| 3B | Las Vegas, NV | 1.54 | 1.82 | 2.08 | 27% | 1.6 | 12.7 |
| 3C | San Francisco, CA | 1.95 | 2.00 | 1.78 | 33% | 1.5 | 13.1 |
| 4A | Washington, D.C. | 3.25 | 2.48 | 1.66 | 28% | 1.3 | 15.5 |
| 5A | Chicago, IL | 4.40 | 0.56 | 1.21 | 23% | 2.5 | 7.9 |
| 5B | Ogden, UT | 3.62 | 0.68 | 1.43 | 23% | 2.4 | 8.3 |
| 6A | Minneapolis, MN | 4.96 | 0.55 | 1.17 | 20% | 2.5 | 8.1 |
| **AVERAGE SAVINGS** | | **2.46** | **1.72** | **1.62** | **24%** | **1.8** | **11.8** |

*Optimized for climate zones: 1A-3C SHGC 0.20, 1A-3C SHGC 0.46.
$32.38/ft$^2$ double-pane $34.87/ft$^2$ quad-pane with thin glass $36.87/ft$^2$ quad-pane with film.
Higher-efficiency windows can reduce HVAC capacity requirements and should be factored into the economics of any new construction or major renovation project.

## DEPLOYMENT

*Where does M&V recommend deploying Lightweight Quad-Pane Windows?*

**ALL NEW CONSTRUCTION**

**END-OF-LIFE WINDOW REPLACEMENT**

Thin-glass configuration is more cost-effective. Suspended-film version offers versatility in low-e coatings, meets tempered glass requirements, and is about 1 lb lighter per square foot than the thin-glass configuration.

[1]Low-e Applied Film Window Retrofit for Insulation and Solar Control, Charlie Curcija, Howdy Goudey, Robin Mitchell, LBNL, February 2017, p. 10
[2]Demonstration and Evaluation of Lightweight High Performance Quad-pane Windows , Kosol Kiatreungwattana, Lin Simpson (NREL), October 2021, p.17 [3]Ibid, p.28 [4]Ibid, p.28 [5]Ibid, p.21

GPG FINDINGS **049**

NOVEMBER 2021

# LIGHTWEIGHT SECONDARY WINDOWS

## OPPORTUNITY

*How much window energy use could higher performing windows save?*

**UP TO 75%** OF THE ENERGY LOST THROUGH WINDOWS COULD BE REDUCED WITH HIGHER PERFORMING WINDOWS[1]

## TECHNOLOGY

*How do lightweight secondary windows work?*

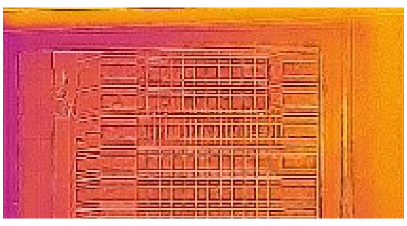
### THIN GLASS IN INSULATED FIBERGLASS FRAME

**PRE-MANUFACTURED LIKE STORM WINDOWS**

Single- & double-pane configurations

2 to 3 times lighter than inserts manufactured with standard glass

Outside temperature 27°
Single-pane interior glass 42°



Outside temperature 27°
Single pane with insert 64°

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** assessed the impact of lightweight secondary windows provided by Alpen High Performance Products in a two-story office building at the Denver Federal Center.

## RESULTS

*How did lightweight secondary windows perform in M&V?*

**15% AVERAGE WHOLE-BUILDING ENERGY SAVINGS** [2]

Savings for double-pane insert with a baseline single-pane window

**EASY INSTALLATION**

< 10 MINUTES FOR 1 PERSON

NO DRILLED HOLES OR PERMANENT DEVICES[3]

**COMFORT INCREASED**

20° WARMER INTERIOR GLASS[4]

73% REDUCTION IN CONDENSATION[5]

97% LESS AIR LEAKAGE[6]

### Cost-Effective Across Climate Zones[7]

Positive return on investment at average GSA utility rates, $0.11/kWh and $7.43/mmBtu

| Location | | Savings with Double-Pane Insert (Single-Pane Window Baseline) | | | | | |
|---|---|---|---|---|---|---|---|
| CLIMATE ZONE | CITY | WHOLE BUILDING ENERGY SAVINGS kBtu/ft²/yr | ENERGY COST SAVINGS $/ft²/yr | ANNUAL SAVINGS $/yr | SAVINGS % | PAYBACK* YRS | SIR positive ROI if >1 |
| 1A | Miami, FL | 8.1 | $0.27 | $14,480 | 11% | 11.2 | 1.59 |
| 2A | Houston, TX | 9.1 | $0.30 | $16,088 | 12% | 10.1 | 1.76 |
| 2B | Phoenix, AZ | 10.7 | $0.35 | $18,770 | 14% | 8.7 | 2.05 |
| 3A | Atlanta, GA | 10.3 | $0.35 | $18,770 | 14% | 8.7 | 2.05 |
| 3B | Las Vegas, NV | 10.8 | $0.36 | $19,306 | 15% | 8.4 | 2.11 |
| 3C | San Francisco, CA | 8.3 | $0.28 | $15,016 | 13% | 10.8 | 1.64 |
| 4A | Baltimore, MD | 12.6 | $0.43 | $23,060 | 16% | 7.1 | 2.52 |
| 5A | Chicago, IL | 13.5 | $0.46 | $24,669 | 17% | 6.6 | 2.70 |
| 5B | Boulder, CO | 13.9 | $0.47 | $25,205 | 18% | 6.5 | 2.76 |
| 6A | Minneapolis, MN | 15.6 | $0.54 | $28,959 | 17% | 5.6 | 3.17 |
| **AVERAGE SAVINGS** | | 11.3 | $0.38 | $20,432 | 15% | 8.4 | 2.2 |

*Modeling for high SHGC-0.42 in a medium-sized office building. A low SHGC-0.20 is more cost-effective in warm climates, with estimated payback < 10 years. Does not include savings from reduced air infiltration. Double-pane insert $22/ft² Single-pane insert $17/ft² Installation $1.15/ft²

## DEPLOYMENT

*Where does M&V recommend deploying lightweight secondary windows?*

### RETROFIT SINGLE-PANE WINDOWS

In cold climates, double-pane secondary windows will be more cost-effective. In warm climates, the single-pane configuration may offer a better return on investment.

This retrofit technology is particularly well suited for historic structures where changes to the facade are not allowed.

[1]Highly Insulating Window Panel Attachment Retrofit. Charlie Curcija, Howdy Goudey, Robin Mitchell, Erin Dickerhoff (LBNL), December 2013, p.3 [2]Demonstration and Evaluation of Lightweight High-Performance Secondary Windows. Kosol Kiatreungwattana, Lin Simpson (NREL), November 2021, p.66 [3]Ibid, p.30 [4]Ibid, p.28, 9° warmer with single-pane insert [5]Ibid, p.22 [6]Ibid, p.28 [7]Ibid, p.66

GPG FINDINGS 050

SEPTEMBER 2022

# ENERGY MANAGEMENT SYSTEM WITH AUTOMATED SYSTEM OPTIMIZATION

## OPPORTUNITY

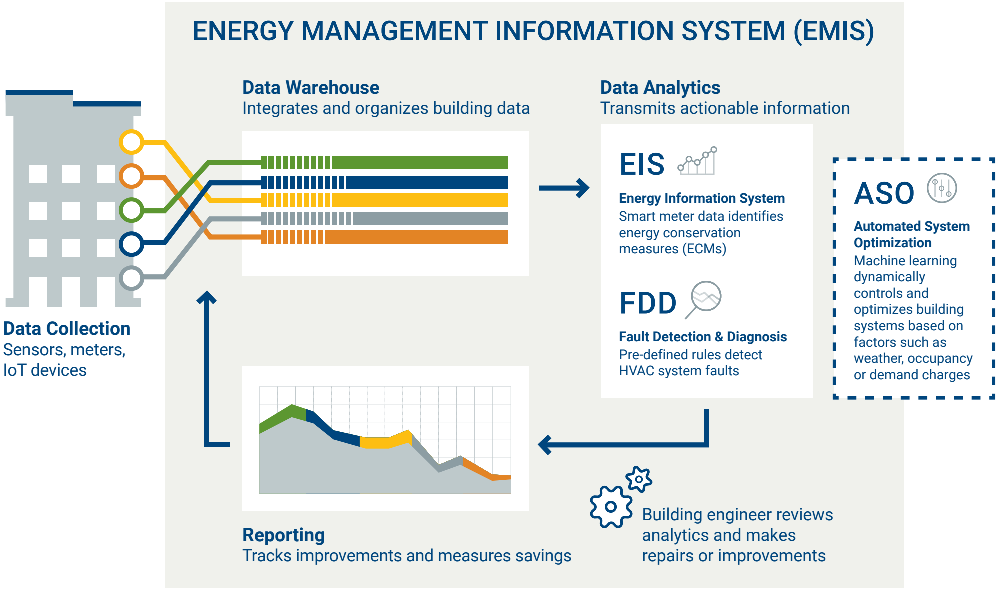
*How much energy can be saved with smarter building control?*

**UP TO 30%** ENERGY USE IN COMMERCIAL BUILDINGS CAN BE SAVED WITH SMARTER BUILDING CONTROL[1]

## TECHNOLOGY

*How does an energy management information system (EMIS) with automated system optimization (ASO) work?*

**Aggregates historical and real-time data with machine learning and thermal modeling to optimize building performance**




Adapted from LBNL (Kramer et al. 2020)[2]

## M&V

*Where did Measurement and Verification occur?*

**NATIONAL RENEWABLE ENERGY LABORATORY** assessed the impact of an EMIS with ASO provided by Prescriptive Data at four testbeds representative of a range of GSA facility types and operating conditions.

## RESULTS

*How did the EMIS with ASO perform in M&V?*

**5-11%** **WHOLE-BUILDING ENERGY SAVINGS**[3] from controlling AHU fan speeds based on weather and occupancy

**95%** **ACCURATE** PREDICTED DEMAND WAS WITHIN 5% OF MEASURED DEMAND[4]

**VISIBILITY INCREASED** WITH MULTIPLE DATA STREAMS[5]

INTEGRATED DASHBOARD REVEALED OPERATIONAL ISSUES[6]

POSITIVE USER ACCEPTANCE[7]

## GSA Market Analysis for Automated System Optimization

Portfolio potential for cash-flow positive facilities based on % savings*

| | 5% Annual Cost Savings | 7.5% Annual Cost Savings | 10% Annual Cost Savings | 12.5% Annual Cost Savings |
|---|---|---|---|---|
| Cash-flow positive facilities (total out of 504) | 90 | 223 | 322 | 424 |
| Total Building Area (sf) | 30,488,470 | 77,028,119 | 106,211,953 | 139,233,885 |
| Gross Annual Cost Savings ($/yr) | $4,538,021 | $12,467,287 | $19,949,064 | $28,689,424 |
| Annual Subscription Cost ($0.10/sf/yr) | $3,048,847 | $7,702,812 | $10,621,195 | $13,923,389 |
| Net Annual Cost Savings after SaaS ($/yr) | $1,489,174 | $4,764,475 | $9,327,869 | $14,766,035 |

* Break-even point depends on utility costs, annual savings, and geographic region. Does not include installation cost due to varying expenses of integration.

## DEPLOYMENT

*Where does M&V recommend deploying an EMIS with ASO?*

**BUILDINGS WITH HIGH ENERGY COSTS**

An EMIS with ASO can simplify building management and should be considered for deployment across the portfolio. Prioritize buildings with high energy costs.

[1]Commercial Buildings Integration Program, U.S. Department of Energy (https://www.energy.gov/eere/buildings/about-commercial-buildings-integration-program, accessed 9-2022) [2]Kramer, H, Lin, G, Curtin, C, Crowe, E, Granderson J. Proving the Business Case for Building Analytics. Lawrence Berkeley National Laboratory, October 2020 [3] Sean Pachuta, Jesse Dean, Alicen Kandt, Khanh Nguyen Cu Field Validation of a Building Operating System Platform. NREL, August 2022, p.iv [4]Ibid, p.iv [5]Ibid, p.33 [6]Ibid, p.33 [7]Ibid, p.32

GSA

The GPG program enables GSA to make sound investment decisions in next generation building technologies based on their real world performance. www.gsa.gov/gpg